1085 Issued May 26, 1908.

HAWAII AGRICULTURAL EXPERIMENT STATION,

JARED G. SMITH, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

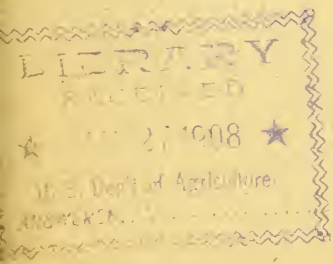
FOR

1907.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS.

U. S. DEPARTMENT OF AGRICULTURE.



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HAWAII AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.]

Walter H. Evans, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

Jared G. Smith, *Special Agent in Charge.*
D. L. Van Dine, *Entomologist.*
J. E. Higgins, *Horticulturist.*
Alice R. Thompson, *Assistant Chemist.*
F. G. Krauss, *In Charge of Rice Investigations.*
Q. Q. Bradford, *Assistant in Rubber Investigations.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, February 15, 1908.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1907.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1907.

SUMMARY OF INVESTIGATIONS.

By Jared G. Smith, *Special Agent in Charge.*

The routine office, library, and laboratory work continued throughout the year on much the same lines as during the previous period of the station's existence. Building operations were confined to repairs to the residences on the station, the erection of an additional stable, and the enlargement of the stable capacity of the main barn where the work animals are cared for.

Congress having appropriated $5,000 for the installation of a water system, the plans which had previously been approved by the Secretary of Agriculture were carried out. A corrugated galvanized-iron roof about 200 feet square was constructed on Tantalus, at an elevation of about 1,200 feet. The iron was laid on purlins of 2 by 6 inch northwestern lumber, spiked to the tops of 5-inch split redwood fence posts, which had been set in the ground to a depth of about 2½ feet. This roofing conformed to the slope of the hillside, the purlins being nailed to the posts, so that when the tops of the latter were sawed they formed successive planes. At the lower edge of this roof a 2-foot gutter leads the water into a 30,000-gallon redwood tank. A 1-inch galvanized pipe leads the water from this 30,000-gallon tank down along the ridge into a 60,000-gallon tank, located immediately above residence No. 2, at an elevation of about 475 feet above sea level. Direct connections will be made from this tank to residences Nos. 1, 2, and 3. Another 60,000-gallon tank has been placed at the upper corner of the lower experimental fields, at an elevation of about 250 feet. Over 1 mile of piping has been laid to conduct water from this lower tank to the experimental plats. The materials for the construction of this water system, including two 60,000-gallon tanks and one 30,000-gallon tank, 12,000 feet of 1-inch pipe, 500 feet of 2-inch pipe, 400 feet of ¾-inch pipe, together with cement, dimension timbers for foundations, nails, roofing screws, pipe fittings, etc., cost $4,006.14. The plant was installed by day labor at a cost for labor and supervision of $993.75, leaving an unexpended balance of this appropriation of 11 cents.

Through delays in the delivery of materials on the part of some of the contractors this water system was not completed until after the end of the rainy season. Nevertheless, the tanks have been kept full practically all of the time, as hardly a day passes when there are not some showers at the elevation where the roof is placed. With an average rainfall amounting to about 120 inches per annum this water system will yield the station 1,250,000 gallons of water, and we now have a storage capacity of 210,000 gallons. This guarantees fire protection to station residences and office buildings, and insures a water supply for the experimental plats during the driest and hottest months of the summer, a period during which in previous years there has always been a shortage in the city water supply.

By using station labor under the immediate supervision of the director this plant was installed at a cost of less than 25 per cent of the cost of the materials used.

In July, 1906, two Wardian cases of cacao and six inarched mangoes were received from the Bureau of Plant Industry of the Department in Washington. A portion of these plants were set out on the station grounds in Honolulu and the remainder placed at Hilo, where previous plantings of cacao had been made.

The distribution of Bluefields bananas begun in May, 1906, was continued during July and August, over 1,000 suckers of this fine type of banana being distributed throughout the Territory.

In a cooperative agreement between the Director of the Office of Experiment Stations and the Chief of the Bureau of Plant Industry Dr. N. A. Cobb, who had been employed as pathologist by the Hawaiian Sugar Planters' Association in the study of the diseases of cane, was given a commission to prepare a report on the fungus diseases of crops other than cane in Hawaii, and this report will be published as a bulletin of this station.

The special agent, assisted by the station horticulturist and entomologist, made representations to the Territorial Board of Commissioners of Agriculture and Forestry in an endeavor to secure their cooperation in a survey to determine the present distribution of the mango weevil. This weevil, which is a very serious enemy of the mango fruit, as has been previously noted, had only recently been introduced into Hawaii, and it was felt that if precautions could be taken in time there was a good opportunity to entirely destroy the pest. The board of agriculture, however, considered that the weevil had already become so widely distributed throughout the group that it would be impossible to do anything, and the matter was therefore dropped. The officers of this station consider it extremely unfortunate that efforts should not have been made at the time of the first discovery of this mango weevil to prevent its further distribution.

The special agent made an extended trip through Maui and Hawaii in an investigation of the rubber industry. He also visited the location on Maui where the variety test of grapes was being conducted. As a result of reports made by him in regard to the suitability of certain lands in Puna, an extensive rubber plantation has been established, which has already (July 1, 1907) over 12,000 trees growing in the fields.

In November, 1906, this station cooperated with the manager of one of the local sisal plantations in an investigation of the sisal industry in Yucatan. Much valuable information was secured, which is available for publication in a second report on the sisal industry in Hawaii.

The special agent has prepared reports in regard to the work of the station for the governor of Hawaii, at his request, and also a report in regard to the cooperative work of the station for publication in the annual report of the Board of Agriculture and Forestry.

During the regular session of the legislature which convened in February, 1907, the director visited the island of Lanai at the request of the house committee, which had been appointed to investigate the Lanai land exchange, and made a report to the legislature on the agricultural possibilities of that island.

Considerable work has been done for other branches of both the Federal and the Territorial government, among these cement analyses for the U. S. Army Engineer Corps, and a number of analyses and examinations of imported goods for the collector of customs. This station has also cooperated with the Navy Department in sending collections of seeds and plants to the naval stations in Guam, Tutuila, and the Philippines.

A number of changes have occurred in the office and staff. The more important of these are the appointment of Mr. F. G. Krauss as agricultural expert in charge of rice investigations, at a salary of $2,000 per annum. Half of this amount during the fiscal year 1907 was contributed by the B. P. Bishop Estate (Limited). The horticulturist, Mr. J. E. Higgins, was promoted from $1,700 to $2,000. Miss A. R. Thompson was appointed assistant chemist, and the former chemist, Mr. E. C. Shorey, was transferred to the Bureau of Soils, U. S. Department of Agriculture.

Besides the $15,000 appropriated by Congress this station has received during the fiscal year 1907 from private and other sources $13,518.63. This includes a balance of $2,267.09 remaining unspent from the Territorial appropriation of 1905. A deficiency appropriation of $2,000 was made by the legislature in May, 1907, to assist the rice, tobacco, and rubber investigations. A Territorial deficiency appropriation of $1,873.86 was received to settle indebtedness which was

incurred in the erection of a fireproof library, laboratory, and office building, for the erection of which the legislature made an insufficient appropriation in 1905.

The Bernice Pauahi Bishop Estate (Limited), contributed $1,000 for rice investigations and $200 for rubber experiments. The Ii Estate (Limited), contributed $128, or its equivalent, in the free rental of 3.2 acres of rice land for the benefit of the rice investigations. The Honolulu Merchants' Association contributed $50 toward the cost of the fruit marketing experiments conducted by the horticultural department. Mr. James B. Castle contributed $358.60 toward the expense of establishing a citrus orchard on Tantalus, and $1,000 for tobacco experiments on Hawaii. The Hawaiian Bee Keepers' Association contributed $675 toward the cost of the entomologist's trip to Washington, D. C., in their behalf. Dr. Wm. S. Myers, of New York city, gave $187.50 for the continuation of the rubber experiments. Mr. George N. Wilcox gave $200 for rubber experiments and $500 for tobacco experiments. Hon. A. S. Wilcox contributed $500 for tobacco. Messrs. Geo. P. Thielen and Joseph P. Cooke each contributed $1,000 for tobacco. The American Sugar Company, the Parker Ranch, and the Stock Breeders' Association gave $175 toward the cost of investigations by the entomologist of insects affecting stock. The receipts from the sale of farm products amounted to $100.88. The total amount expended for this station during the fiscal year 1907 was $33,518.63, of which $20,000 was appropriated by Congress.[a]

During the year three press bulletins were issued—No. 17, The Mango Weevil; No. 18, All About the Hawaii Experiment Station; and No. 19, A Preliminary Report on Rice Investigations. Editions of 4,000 copies of each of these bulletins have been distributed.

CHEMICAL INVESTIGATIONS.

The only project completed during the year has been that of honey analysis. This work has been carried on by the station chemist, Miss Alice R. Thompson, in cooperation with the entomologist. Complete analyses were made of 49 samples of honey of known derivation and the results of this work are now available for publication.

Considerable routine work was accomplished, including a number of miscellaneous soil analyses, the analyses of waters to determine the relation of their salt content to the growth of rice and other irrigated crops, analyses of rubber, soils, and of additional samples of Hawaiian feeding stuffs.

[a] Besides these cash contributions the station is indebted to the Interisland Steam Navigation Company (Limited), of Honolulu; The Oahu Railway and Land Company (Limited), of Honolulu; The Kahului Railroad Company (Limited), of Kahului, Maui; and the Hilo Railway Company (Limited), of Hilo, Hawaii, for gratuitous transportation of the members of the station staff.

Early in the year connections were made with the mains of the newly organized gas company, so that we were able to discontinue the use of the cumbersome and costly gasoline gas machine, upon which the station had previously depended for its laboratory supply.

TOBACCO.

As has been noted above, the station received the benefit of $4,000 in private contributions for continuing the tobacco investigations, concerning which a number of reports have been issued. In January, 1906, the station was given the use of lot 19, Paauilo Homestead, a body of land about 1 mile distant from the plat which had previously been leased from the Louisson Brothers, in Hamakua, Hawaii. At the request of the special agent, the acting governor of Hawaii, Hon. A. L. C. Atkinson, secretary of the Territory, confirmed a reservation made by Hon. James W. Pratt, commissioner of public lands, reserving lot 19 for the use of the station for a period of three years. Field work was not begun until February 15. Three thousand dollars of private funds being at that time available, the work of preparing land for planting was immediately begun. A part of the land was cleared of the abandoned coffee, with which the land was covered, along with weeds and grass. About 2 acres was then plowed and 3 acres intended for immediate planting was partially hoed and then cultivated. As soon as the ground was in shape transplanting was begun. Work was commenced so late in the year that we were able to plant only about 3½ acres, instead of 5 or more, as originally planned. As soon as the field work was under way lumber was purchased for the erection of a curing barn and fermenting shed, seed houses, and labor quarters. A curing barn capable of handling 5 acres of tobacco was rushed to completion, but even then some of the tobacco was overripe before the structure was finished. About $2,500 of the amount privately contributed was expended for buildings and other permanent improvements. The work was begun late in the year, so that everything was hurried during the entire season.

The results were better than in any previous season. The entire crop was cured and fermented in the new tobacco barn, and, although probably 600 pounds of the crop was lost through ripening before we were ready to care for it, a crop of 3,000 pounds of cured tobacco was secured from 3½ acres of land. A quantity equal to 6 or 7 bales has been distributed in small amounts to tobacco dealers in the United States and Europe. Two New York firms received 1 bale each, and the station now has on hand 23 bales of finished tobacco. The best tobacco grown this year was the Sumatra, although the Cuban grades were of very excellent quality. The reports in regard to the quality of our tobacco are uniformly favorable, buyers being very enthusi-

astic in regard to colors, texture, and burn of leaf. The tobacco is very mild and of excellent flavor.

The legislature at its session early in 1907 having omitted its appropriation for assistance to this station, the demonstration with this crop was discontinued. It is believed that this demonstration, which has been continued over a period of three years, has definitely established the fact that cigar-leaf tobaccos of the very best wrapper and filler types can be produced on a commercial scale in certain favorably located districts in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

In July and August, 1906, the entomologist finished his work with the distribution of the top-minnows. He personally distributed a number of these mosquito larva-eating fish on the windward side of Oahu, in the vicinity of Hilo, on the island of Hawaii, and on several points on the island of Kauai. This distribution having been completed, this line of investigation was discontinued.

In September, 1906, a request was made for the services of the entomologist in the control of a serious outbreak of pineapple insects on the island of Kauai. The cause of serious losses among fields of newly set pines was found to be the pineapple scale and the pineapple mealy bug. Experiments were made both in dipping and in fumigating the suckers which were being transplanted. It was found that the hydrocyanic-acid gas method was entirely efficacious, cheap, and easy of application.

The principal entomological work of the year has been an investigation of the problems affecting the honey industry in Hawaii. The entomologist has visited all the principal apiaries and has made a very exhaustive study of the conditions of the industry. Fifty-four samples of honey of known origin were collected; 49 of these were analyzed by the station chemist.

Hawaiian honeys are largely of a type entirely different from those of the mainland. The present annual production amounts to upward of 600 tons. One-fourth of this, or about 150 tons, is honeydew honey, the source of which is not floral nectar, but the secretions of insects affecting the sugar cane and other sugar-producing plants. About 250 tons are a mixture of honeydew honey and floral honey, compounded by the bees during the time when there is a shortage of floral nectar. About two-thirds of a crop is therefore of a type but little known on the mainland. This pure honeydew honey and the mixed honeys are sold to the baking trade, and do not enter into competition with any of the natural product offered for sale in the retail markets.

Through the efforts of the entomologist the prices obtained by producers of this honeydew product have been much increased. Be-

fore their baking qualities were ascertained, the Hawaiian honeydew honeys entered into more direct competition with Australian and other cheap grades, which are most largely used in the manufacture of shoeblacking and in other special lines of industry. In former years, when only this market was known to be open, prices ranged from 2 to 3 cents per pound. Now, through the efforts of our entomologist, large consignments have been sold to the wholesale baking trade, prices ranging from 4 to 6 cents per pound being realized.

Bakers and confectioners consider honey of this type, on account of its noncrystallization, as much more valuable in their industry than the grades obtained from purely floral sources.

On April 5, 1907, the entomologist left for Washington for the purpose of taking up with the Chief of the Bureau of Chemistry the question of the conformity of Hawaiian honeys to honey standards. Subsequent to the passage of the Food and Drugs Act, the question had arisen whether or not Hawaiian honeys of the pure honeydew and mixed honeydew types were or were not adulterated. Mainland buyers claimed that these honeys were not pure. The analyses of Hawaiian honeys, made by the chemist of this station, had plainly indicated that while these honeys are pure in the sense that they are not artificially adulterated, there is wide divergence in their analysis from previous honey standards.

While somewhat abnormal in their constituents, these honeys are recognized as natural products, and as such can be marketed if properly labeled. Those polarizing to the left will be recognized as pure honey, while those polarizing to the right should be marked in a distinctive manner, and the name "honeydew honey" has been suggested for them.

In connection with this honey work a beginning has been made in the investigation of the feasibility of feeding back the inferior grades of pure and mixed honeydew types for the production of wax. Wax of good quality sells for from 35 to 40 cents per pound, while honeydew honeys sell from $2\frac{1}{2}$ to $4\frac{1}{2}$ cents per pound. If it proves practicable to feed back this grade of product, or, more properly, if 1 pound of wax can be produced by feeding back from 4 to 8 pounds of honey, there is bound to be a wider margin of profit in the production of wax than through the marketing of this cheap grade of honey.

Studies were also made of the races of bees with a view to improvement of the local breeds.

Another line of investigation which has been begun is a study of the insects affecting live stock, among these being flesh flies, horn flies, mites, ticks, bots, fleas, and other pests. On his return from Washington the entomologist visited some of the ranches in Texas and southern California, making preliminary studies of the conditions affecting pests of stock in these sections of the country.

Investigations were continued on household pests and pests infesting stored products, and a demonstration was made of methods for the control of the cigarette beetle in tobacco and cigars. The cigarette beetle occurred in a new rôle as a household pest, being discovered in enormous numbers in a residence in Manoa Valley infesting the paste underneath the wall paper.

Other outbreaks of minor importance were investigated, such as an epidemic of fleas in several sections of the city. Considerable losses in furniture and basket ware, caused by termites, various wood-boring insects, and the bamboo beetle, were prevented.

As the rubber industry is attaining considerable proportions, studies have been commenced of the injurious insects affecting rubber trees. The entomologist visited the rubber plantations on Maui, and has made studies of the life histories of some of the bark and wood-boring insects with a view to their control.

HORTICULTURAL INVESTIGATIONS.

The principal work of the year was a fruit shipping experiment. The horticulturist left Honolulu August 1, 1906, taking with him about 4 tons of pineapples, avocados, papaias, and bananas. This shipment was landed in San Francisco August 7 and was transshipped at once to Portland, Oreg., where the entire shipment was unpacked and examined. A portion of it was disposed of in Portland and the horticulturist took the remainder to Astoria, Tacoma, Seattle, and Vancouver. Returning to San Francisco he visited Fresno to investigate the sweet-potato industry. He also investigated the general fruit markets in San Jose, Stockton, Sacramento, and Oakland, and, before returning, visited Luther Burbank's gardens in Santa Rosa. The object of this comprehensive experiment was to determine the best methods of packing, handling, and marketing tropical fruits. An investigation was also made of the extent of the market for these fruits on the Pacific coast. Selected packages were shipped to commercial bodies and to the governor of each of the mountain States as far east as Colorado. One package of pineapples was shipped to the special agent in charge of the Alaska Experiment Station at Sitka. This experiment demonstrated the possibility of the shipment of avocados and pineapples in cold storage to any point which can be reached by direct shipment from Honolulu, Hilo, and other island ports. Interesting facts were determined in regard to methods of packing and the use of different styles of crates. The most striking feature of the whole experiment was the demonstration of the value of fumigation with formaldehyde gas to prevent the losses caused by the pineapple rot, *Thielaviopsis ethaceticus*.

This fungus is the cause of the disease of sugar cane known as the pineapple disease; so-called, not because it was originally a disease of pineapple, but on account of the odor which is produced in cane affected by this disease. In cane it is a disease of the ripe stalk, the fungus attacking the plant at the stage when it contains the most sugar. When this fungus attacks the pineapple it is chiefly in evidence during the ripening of the fruit and does not apparently affect any other part of the plant. It has been demonstrated that infection of the pineapple fruit occurs at the base, either through wounds caused by mealy bugs and other sucking insects, or where the fruit has become bruised or injured through the tearing off of the bracts which subtend the fruit. The fungus also gains entrance to the fruit through the fresh surface of the cut stem. Positive results were obtained when these bracts were cut instead of being pulled, and equally positive results were obtained by cutting the stalk 2 or 3 inches below the fruit. Preliminary experiments were made in dipping the fruit in a 4 per cent solution of formalin, but it was found that this method caused changes which would interfere with the attractiveness of the fruit. It was found that fumigation caused none of these changes, but did exercise a definite control to prevent infection. The fumigated fruits which were lost by rotting in transit were those which were apparently seriously infected previous to shipment and previous to fumigation. It was demonstrated that a favorable method of fumigation is that proposed by the Maine State board of health, through the use of permanganate of potash and commercial formalin. A full and detailed account of these experiments was published in a bulletin of this station.[a]

Other points which were determined in regard to pineapples are the value of glazed paper as a wrapping material for the fruit. By the substitution of paper for hay or straw, which substances are commonly used in the packing of Hawaiian fruit intended for shipment, the package can be decreased at least one-third in size and the weight also very considerably diminished. Pineapples that were wrapped in paper reached the market in very much better condition than those packed with hay in crates.

The permanent orchards on the station were largely increased during the year 1907. The avocado and mango orchard was extended so that about 1½ acres are now planted with budded, grafted, and inarched stock of many of the best varieties.

Through the cooperation of Mr. James B. Castle, about 2 acres of land were cleared on the upper portion of the place at an elevation of about 1,000 feet. This has been planted with a collection of some of

[a] Hawaii Sta. Bul. 14.

the best Californian varieties of citrus fruits, figs, loquats, and grapes. About one-third of an acre has been planted with papaias for breeding and crossing work. A large number of seedling citrus trees have been set out with a view to making in this location a bud collection of the best island types. Besides contributing funds for clearing the land and planting it, Mr. Castle has volunteered to care for the orchard during the coming year.

A large collection of rubber plants and miscellaneous economic plants has been set out on the clearings above the 1,000-foot level. These were all grown by us in our greenhouses from seeds purchased from dealers in tropical seeds and plants.

On the lower part of the place about 4 acres of new land has been planted, as follows: One acre of mulberries, obtained through the Bureau of Entomology, U. S. Department of Agriculture. This planting represents the best varieties for the production of silk, so that the station will have its own supply for further investigations in this line of work. One acre has been planted with citrus trees including grapefruits, oranges, lemons, and limes. One acre has been set with 5 species of rubber—*Castilla elastica*, *C. lactiflua*, *Manihot glaziovii*, *Cryptostegia madagascarensis*, *and C. grandiflora*. The remaining acre has been planted with a miscellaneous collection of tropical fruits and economic plants, including stock grown in our own greenhouses and plants supplied by the Seed and Plant Introduction of the U. S. Department of Agriculture.

About 1½ acres of roselle was cultivated on the lower part of the station as a demonstration of the practicability of growing this fine fruit. A quantity of the fruit was sold, and a good many lots were distributed for the purpose of demonstrating its value in the making of jams and jellies. Seed was saved from selected plants and has been widely distributed throughout the Territory.

The horticulturist visited the Parker ranch, on the island of Hawaii, supervised the setting out of a large deciduous orchard, consisting of apples, pears, plums, peaches, apricots, cherries, walnuts, almonds, and figs. Two orchards of deciduous fruits have been established on the Parker Ranch, one at an elevation of about 3,000 feet, on the northeastern end of the ranch, and one at 5,000 feet in the Waiki district. This cooperative experiment will undoubtedly prove of great value in subsequent years.

The horticulturist had the general supervision of a fruit exhibit in connection with the agricultural show held in Honolulu, December, 1906. In cooperation with the Hawaiian Poultry Association the horticulturist prepared an exhibit under the joint auspices of the Farmers' Institute of Hawaii and the Hawaii Agricultural Experiment Station.

RUBBER.

In the summer of 1906 attention was called to the existence of two groves of rubber trees on the island of Kauai, each containing about 100 individual trees. One of these groves, at Koloa, was planted in 1893, and seed from these trees was planted at Lihue in 1899, so that the two groves are, respectively, 13 and 7 years old. These trees are of the Ceara variety, which is being extensively planted in these islands.

It was at once suggested by some of the planters interested in rubber cultivation that this station make a tapping experiment to determine the amount and quality of rubber obtainable. As this station had no funds, work was not begun until January 1, 1907, when the B. P. Bishop Estate (Limited), and Mr. George N. Wilcox each contributed $200 to assist the work.

The first work done was on a few isolated trees from 4 to 10 years old on the experiment station grounds in Honolulu. Three months were devoted to laboratory investigations in regard to the behavior of the latex under different coagulents. Some preliminary work was done to determine the form of tapping tools and method of tapping.

In April, a satisfactory method having been worked out, the special agent, accompanied by Mr. Q. Q. Bradford, farm foreman, went to Lihue. The management of the Lihue plantation lent the station hearty cooperation, erecting a small shed in the rubber grove and providing entertainment and horses for the use of our foreman. The Lihue grove of 7-year-old trees occupies an old taro patch in the bottom of a gulch. Surrounding it is a planted forest several hundred acres in extent. A living stream of water runs through the middle of the grove and the land is quite swampy. The trees vary greatly in size, from 6 inches to 30 inches in circumference of trunk, at 3 feet from the ground. No care appears to have been given the trees during the entire period of their growth. Some of the trees show a clear, straight trunk, 30 feet in height; others fork near the base. It was found that only about 70 trees out of the full number, 110, were suitable for tapping, owing to their size or shape.

A set of rubber tapping knives such as are used in Ceylon for work on Hevea had been purchased, but it was soon found that these were entirely unsuited for thin-barked trees like the Ceara, and considerable work was devoted to making a form of knife which would be satisfactory. After many experiments the system of tapping decided upon was the half herringbone, with one vertical cut and laterals a foot apart extending half around the tree. Where the full herringbone system was employed it was found that only the uppermost and lowest laterals yielded a full flow of latex. Two experiments were outlined, one to tap every day, the other alternate days.

The Ceara latex coagulates almost at once when the channels are made. We therefore adopted a method of trickling water over the cut surfaces, and soon found an addition of ammonia retarded coagulation and continued the flow until the feeding area was practically exhausted. The mixed water and latex is collected at the foot of the tree. The tapping was begun at 5 o'clock a. m. Two trees averaging 28 inches in circumference were tapped for nine consecutive days, with the full herringbone system from the ground to 5 feet, there being five laterals 1 foot apart. These two trees yielded 8 ounces of dry rubber in nine days. Two other trees were tapped on alternate days for a period of two weeks and yielded 4 ounces of dry rubber in that time.

Work was begun at Koloa in May. The trees, 44 inches in circumference and 13 years old at the time tapping was begun, were almost bare of leaves, the resting period being about ended. Two of these 13-year-old trees were tapped every day for nine days and yielded $12\frac{1}{4}$ ounces of dry rubber. It was not considered advisable to tap alternate days on account of the leafless condition of the grove.

In June a number of 4-year-old trees at Koloa, averaging 19 inches in circumference, were tapped every day for 9 days, yielding only $\frac{1}{2}$ ounce of dry rubber. These trees were entirely bare.

This tapping work has been very suggestive, and there are many points that have arisen which we shall endeavor to work out during the coming year. The Ceara trees seem to be very susceptible to the atmospheric and other conditions, at least as far as the flow of latex is concerned. The flow is apparently greatest in the early morning at about sunrise. The amount of sunshine received by the tree apparently has some influence on the amount and flow of latex. These experiments are only in the preliminary stage, and it is too soon to draw conclusions, but if any results can be predicated the indication very strongly suggests the value of daily tappings rather than tapping the tree at longer intervals. Trees tapped late in the forenoon, at midday, or in the afternoon, yield almost no latex. At about sundown there is apparently an increase of tension and the latex flows more freely.

Four-year-old trees at Koloa yielded at the rate of 10 ounces of dry rubber per tree per annum, supposing it possible to tap every day. Seven-year-old trees at Lihue yielded at the rate of 10 pounds per tree, while 13-year-old trees at Koloa yielded at the rate of 15 pounds of dry rubber per tree. Neither the Koloa nor Lihue trees were in good condition at the time of tapping. Those at Lihue are in a swampy location, where the ground is always saturated with water. Those at Koloa are in a much drier location, but have been choked with guava and lantana and overrun with vines. All the tappings were made while the trees were just entering their period of rest or

during the time when bare of leaves. Nevertheless, the results are encouraging. The indications are that the Ceara rubber tree will grow in almost any location in these islands, from sea level to 2,000 feet, and wherever the conditions are sufficiently favorable to permit the attainment of a trunk diameter of 7 or 8 inches these trees will yield an enormous quantity of rubber of most excellent quality.

The quality of the rubber has been good. The variations in quality apparently depend more upon the coagulating medium than upon the character of the latex itself, although in this respect there is wide variation. A great many experiments have been made with various methods of coagulating the latex, but it is too soon to announce results. The best qualities thus far produced have been made by neutralizing the ammonia in the latex and coagulating by adding a hot concentrated solution of ammonium sulphate to which a small amount of formalin has been added. Other coagulents that have been experimented with are acetic acid, sulphuric acid, tri-chloric acid, formic acid, sea water, ammonium sulphate, various copper and other mineral salts, sodium sulphate, etc. A very excellent quality of rubber may be separated out by simply churning the mixture of water and latex. Sulphuric acid gives goods results, provided but little more than enough to neutralize the ammonia in the mixture is used. An excess of sulphuric acid apparently causes deterioration in the quality of the rubber.

RICE.

An investigation of the problems of the rice industry was begun July 1, 1906, funds for the purpose of a cooperative experiment having been provided by the Bernice Pauahi Bishop Estate (Limited), and the Ii Estate (Limited). The trustees of the Bishop estate gave $1,000 for this work, and the Ii estate contributed the lease of 3.2 acres of rice land, located at the junction of King street and Kalakaua avenue, in the city of Honolulu. Mr. F. G. Krauss, who had been agricultural instructor at the Kamehameha Boys' School for the preceding five years, was appointed an agricultural expert in this office to have charge of the work. Operations were commenced about August 1, 1906, and consisted of variety tests of 130 different rices obtained in the islands through the Bureau of Plant Industry, U. S. Department of Agriculture, and through the bureau of agriculture, Manila, P. I. In addition careful selections had previously been made from individual plants, representing some of the best strains of rices now being grown in Hawaii. Two crops of rice have been grown during the period from August 1, 1906, to August 31, 1907.

The results of the variety test have been that one variety, seed of which was originally obtained by Dr. S. A. Knapp in Egypt, has proved to be better than any rice ever grown in these islands. This

Egyptian strain has a very large, flinty grain, heavy panicle, heavy straw, good leafage, and is of the type demanded by the largest consuming trade in these islands. Its milling qualities are very much superior to those of any other variety which has been produced in the islands, the hulls approximating only 20 per cent of the total weight of paddy, as compared with from 26 to 30 per cent for the best Japanese types, and 28 to 36 per cent for the ordinary Hawaiian variety. In addition to this Egyptian type three other strains have shown marked superiority to the ordinary Hawaiian-grown rices. These are, in order of merit, a Philippine variety, a strain of the Gold Seed from Georgia, and a Japanese type, seed of which was secured direct from Japan.

This Japanese variety produces a crop in three-fourths the time required for the maturity of the Hawaiian variety, provided it is transplanted from the seed bed at the proper time. It is of the Kiushu type, yields as heavily as the Hawaiian variety, mills from 10 to 12 per cent better, produces only about two-thirds the amount of straw, and is therefore less exhaustive on the rice lands. It is the type of rice now most largely consumed in Hawaii by the Japanese laborers on the plantations. A further advantage of the adoption of this variety will be that two crops can be grown each year, with a long rest between crops to permit the drainage of the fields and their better tillage and preparation. The station now has 50 pounds of this seed on hand, and will probably have 1,000 pounds at the end of the next crop. The field was thoroughly rogued and the strain is being propagated from the best individual plants of the whole field, thus laying the foundation for the production of pedigree rice.

The so-called Hawaiian rice is derived from original Gold Seed, South Carolina stock, the first rice cultivated in Hawaii having been thus obtained. The Georgia variety, mentioned above, is hardly to be distinguished from Hawaiian rice. A number of selections have been made of individual plants showing the best individual characteristics in yield of grain, form of panicle, stalk, and leafage, and vigor of growth. An increase of 25 per cent of yield of paddy has already been produced from only the second selections from individual plants. The advantage of this use of pedigree stock of seed derived from a single parent is greater uniformity in the size of grain, the yield, and the time of ripening. The substitution of such pedigree stock will tend to decrease the very large milling losses which have been characteristic of the Hawaiian rice industry. The ordinary Hawaiian rice, while largely of the Gold Seed type, is really a mixture of a great many different types, so that to get the best results in harvesting some of the rice will be so ripe that the grain shatters, while a portion of the plants in the field have perhaps barely attained a sufficient degree of ripeness to warrant their being cut. The losses in milling are

due to the varying sizes and types of grain and their varying stages of maturity. The miller sets his burrs to accommodate the average size of grain in the run, so that grains which are too large are broken and those which are smaller than the average are insufficiently milled, causing bad color in the product.

The uniformity of grain will undoubtedly prove of greater importance than any other single factor in the production of this crop. This uniformity can be produced only by the production of pedigree stock; that is, stock derived originally from a single parent plant.

Three varieties of dry-land rice have been selected from the original variety collection. An interesting point about these dry-land rices is that they produce a better crop without irrigation than with it. The value of dry-land rice is going to be not so much the production of grain, because dry-land rices tend toward the starchy type of grain rather than the flinty, but the production of forage. The culm and leafage of the dry-land types of rices are soft and pliable, lacking the silica that causes the harshness of irrigated sorts. These strains produce a quality of hay which is greedily eaten by horses and cattle. The present outlook is that dry-land rices will fill a very important need in Hawaii in the production of hay and forage.

Fertilizer experiments have been conducted for two crops in pot, plat, and field experiments. While it is perhaps too early to draw conclusions, the indications are that an increase of from 15 to 20 per cent of grain per acre can be induced by use of commercial fertilizers of suitable composition.

Early in the year orders were placed for a number of types of agricultural machinery not hitherto used in the rice industry in Hawaii. These included disk tillage implements and the twine binder. Disk tillage is promising, provided machinery can be secured which will give a penetration of from 6 to 8 inches. The type of cut-away, or disk plows and disk harrows, which the station has secured, would only penetrate about 4 inches, although the manufacturers claimed a much greater penetration. It was found that 4.5 acres of rice land could be plowed per day with a 5-foot cut-away bog plow and four horses, as against from 1 to 1½ acres with two water buffalo, or from three to four horses on a 10-inch mold-board plow turning the soil to a depth of about 6 inches. This is the only advantage which this form of implement has over the improved types. If manufacturers of disk implements will evolve a type of bog plow that will turn the ground from 6 to 8 inches in depth, there is no doubt that they would be immediately adopted by the Chinese rice growers.

A number of trials were made in the harvesting of rice with a 5-foot twine binder harvester, and it is believed that the Chinese rice growers would adopt this type of machinery if they could secure a lighter machine.

With an extra week's drainage previous to harvesting, fully one-half of the total area of rice lands in Hawaii can be harvested by means of machinery. The results of the preliminary harvesting tests indicated that even with our comparatively heavy machine one good team of two heavy draft horses, or from three to four medium horses and three men—that is, a driver and two men to follow the machine and shock the grain—will do the work of from 25 to 40 men cutting with a sickle. The increasing shortage of labor in the rice fields and the corresponding increase in prices of day labor will make the substitution of machinery for hand methods imperative. The expert in charge of rice investigations is in correspondence with a number of manufacturers in the United States to see whether a light machine can not be produced which will do the work required of it.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

INTRODUCTION.

Correspondence, the collection of economic insects, the entomological library and records demand a great part of the time of the entomologist. The collection contains only the principal injurious insects of the islands, together with allied species and some of their parasitic and predaceous enemies. The specimens are arranged in exhibition cases, are authoritatively determined, and form no small aid in acquainting those interested with any particular species under consideration. To combat intelligently an insect pest the individual must know the appearance, form, life history, and habits of the species and the nature of the injury. To this end the collection is principally devoted.

As to the records, their units seem insignificant alone, but together they form a detail of information that can be brought together with effect in dealing with an insect of economic importance. The value of these records will increase as accessions are made from year to year.

Important additions have been added to the library during the year. Those relating to Hawaiian entomology are included in this report.

The writer visited Wahiawa, Oahu, and Koloa and Lihue, Kauai, to study further the insects affecting the pineapple. Trips were made to Pearl City and Waianae, Oahu, in the interests of bee keeping. Personal investigations relating to the scale insects attacking the mango and fig and spraying experiments to control the same were made at Moanalua, Oahu. Detailed studies of the insects affecting live stock in Hawaii were begun on Molokai. A trip involving three months' time was made to Washington, D. C., southern Texas, and southern California, in the interests of Hawaiian honey, plants suitable for introduction into Hawaii for bee pasturage, and insects affecting live stock.

The writer takes advantage of this opportunity to express his gratitude for continued courtesies extended during the year by mainland and foreign workers. Particular mention should be made of the

helpful aid in information, suggestions, and determination of material received from Dr. L. O. Howard and his associates of the Bureau of Entomology of the United States Department of Agriculture.

INSECT INJURY IN HAWAII.

In Hawaii the relative loss from insect injury is considerably higher than on the mainland of the United States. In the latter it is estimated to be not less than one-tenth of all farm crops. Local opinion has been molded to attribute the unusual injury from insect pests in Hawaii to the fact that Hawaiian conditions are radically different from those of other countries, and especially those in other portions of the United States. This explanation is a very plausible one when supported by the further facts that the country is insular, one of the most isolated portions of the earth's surface, semitropical in climate, and the injurious species of insects are introduced from abroad, and in the majority of instances are unaccompanied by their special parasitic or predaceous enemies. The conclusion is that remedies applicable elsewhere are not practical here. However, the "peculiar nature" of Hawaiian insular conditions and climate comes far from explaining the reason for the greater ravages of Hawaii's insect pests. The term "peculiar" has come to possess an importance it does not deserve.

Hawaii has conditions peculiar to no other country, but in that respect is similar to every other country—each differing according to its own altitude, latitude, and climate. Details of the differences in pests, crops, methods of agriculture, climate, and differing habits of the host or pest under the varying conditions of location will indicate modifications in the methods of insect warfare to be employed. It is to be admitted that conditions peculiar to any country or locality necessitate a variation in the methods of insect control, but this variation is only in the methods and not in the fundamental principles underlying the science.

The following conditions contribute to the relatively high ratio of insect injury in Hawaii as compared with the percentage of loss on the mainland:

(1) Cultural methods in relation to insect injury and the use of insecticides have been little understood on the plantation and on the farm. Until there is a more general effort to control the insect pests of Hawaii by cultural and direct measures, it will be unfair to compare conditions in Hawaii as regards insect injury with those of another country where such measures are universally employed.

(2) Sugar-cane is the principal agricultural crop of Hawaii. An enemy of this plant has necessarily a great advantage because of the immense area devoted to its cultivation. Aside from the advantage of abundance of food, the growth of cane, unlike wheat or corn in a

temperate climate, is continuous. In any locality it is possible to find sugar-cane in various stages of development at all seasons of the year. Not only an abundance of food, but a continuous supply is assured. Further, until recent years varieties of cane and its culture were not considered in their relation to insect injury. Thus when an introduced pest, the sugar-cane leaf-hopper (*Perkinsiella saccharicida*), made its advent into the cane fields several years ago, its injury amounted to millions of dollars.

(3) There is no check to insect development in Hawaii by radical changes of temperature, the equable climate favoring the development of brood after brood throughout the year.

(4) The efforts of diversified farming have been undertaken, in the majority of instances, on land recently cleared and in the midst of areas not under domestication. These smaller areas under cultivation have naturally attracted a horde of injurious insects, present in the locality but inconspicuous because of the check that natural conditions enforce. Further, the individuals undertaking the efforts of farming have in many instances not been farmers and have been unprepared for insect injury and helpless when the destruction of the crop has been threatened.

(5) Horticulture is an undeveloped industry. The effort to produce fruit is confined mainly to trees and vines growing under most adverse conditions in crowded dooryards, uncultivated and uncared for. The percentage of insect injury is abnormally high under these conditions.

(6) Crop rotation, a powerful factor in the control of injurious insects in many countries, is not practiced in Hawaii. Agriculture in Hawaii is not a combination of general farming industries, but is necessarily devoted to crops that must seek the world's market and are thus highly specialized.

(7) Injurious species of insects have been introduced without their special parasitic and predaceous enemies. This has given a great impetus to the development of some species because of the absence of one of nature's important checks. A great deal has been done on the part of the local government to remedy this condition by the introduction from abroad of many important special enemies of some of the more prominent insect pests.

(8) While legislative action is rigidly enforced to prevent the further introduction of injurious insects, no regulations have been outlined or enforced for the destruction of injurious species already established. There is little incentive for an individual to destroy the pests of his own trees and plants when indifferent owners all about him are allowed to breed unlimited numbers of the same species.

THE SWEET-POTATO WEEVIL.

(*Cylas formicarius.*)

The sweet-potato weevil (see fig. 1) appeared in injurious numbers in sweet potatoes at the Lahainaluna School on the island of Maui in January, 1907. Specimens of infested potatoes (see fig. 2)

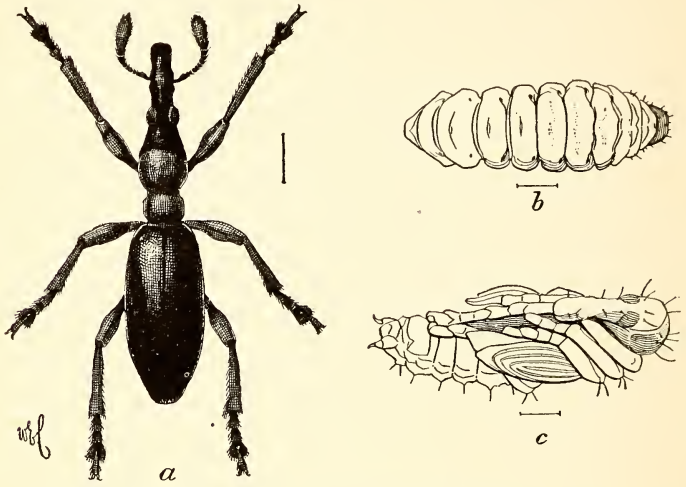

FIG. 1.—The sweet-potato weevil (*Cylas formicarius*): *a*, adult; *b*, larva; *c*, pupa. All greatly enlarged. Natural size shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

were received from Mr. Charles Flack, at that time agriculturist of the school. The crop was nearing maturity and was practically destroyed. The insect is of long standing in Hawaii, being recorded

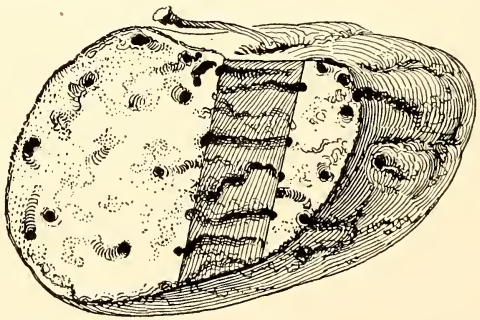

FIG. 2.—Injury to sweet potato by larvæ of the weevil (*Cylas formicarius*). (Drawn for the author by Mr. W. E. Chambers.)

by Blackman and Sharp from the islands of Maui and Oahu in 1885 under the name of *Cylas turcipennis*.[a]

[a] Memoirs on the Coleoptera of the Hawaiian Islands. Sci. Trans. Roy. Dublin Soc., 2. ser., 3 (1885), p. 253.

This is the first local injury that has come to the attention of the writer. Should the attack of this weevil on sweet potatoes become general it would mean a great hardship to the Hawaiian people in some of the outlying districts, since this crop supplies the staple article of food in many localities.

A common plant in all sandy soil along the seacoast of the islands is a vine the name of which is Pohuehue (*Ipomœa pes-caprœ*). This vine is likewise a food plant of the sweet-potato weevil and the destruction of this plant in the neighborhood of sweet-potato fields would be a good precautionary measure. The writer advised Mr. Flack to dig the potatoes and destroy those unfit for use, and cease to plant that crop for one or two seasons, substituting some other crop to replace the sweet potato on the school table. On the advice of Mr. J. E. Higgins, horticulturist of the station, the Polapola banana (*Musa fehi*), a cooking banana of good quality, was recommended to replace the affected crop.

Le Conte and Horn record the sweet-potato weevil in 1876 from Cochin China, India, Madagascar, Cuba, and Louisiana.[a]

Comstock in 1880 reports the destruction of sweet potatoes by this insect in Florida and gives the following description of the weevil and its life cycle:

> The beetle is somewhat ant-like in form. The color of the elytra [wing covers] and of the head and beak is bluish black; that of the prothorax is reddish brown. The yellowish-white oval eggs are laid in small cavities eaten by the parent beetles near the stem end of the tuberous roots. The milk-white larvæ bore little tunnels through the root in all directions, so that the vine dies; and frequently the entire potato is tunneled; these burrows become filled behind the larvæ with excrement. When about to assume the pupa state, the insect forms an oval cavity at the end of its burrow, where it undergoes its transformation.
>
> At the time of my visit to Manatee County, in February, only the perfect insects could be found. On the 17th of May potatoes containing eggs and beetles with a few pupæ were received from Mr. Curry. In our breeding jars these underwent their entire transformation from egg to imago in about thirty-one days, of which eight days were passed in the pupa state. From this it appears that during the present season there have already been at least three generations, and it is impossible to say how many more may appear.[b]

In regard to remedies for the sweet-potato weevil, Riley and Howard say:

> Up to the present time no remedy has been found except to burn all potatoes which are found to be infested. If this should be carefully and thoroughly done throughout a neighborhood, the pest could be greatly reduced. * * * Where it has been abundant in Florida it has been practically stamped out by following the measures just recommended.[c]

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[a] Rhynchophora of America, North of Mexico. Proc. Amer. Phil. Soc., 15 (1876), p. 327.

[b] Report of the Entomologist, Rpt. Comr. Agr. 1879, Washington, 1880, p. 249.

[c] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 5, 1893, p. 261.

In referring to the sweet-potato weevil in Jamaica, the same writers say:

> It seems that only tubers of a certain size are attacked, and early digging sometimes avoids the attack. Sandy soil and deep planting are said to be preventives to some extent.[a]

Undoubtedly the destruction of an infested crop will better insure freedom from attack in the succeeding crop. Deep planting, however, can not be practiced in Hawaii, since cuttings and not tubers are used for seed. After the cuttings have rooted, deep hilling could be employed and the same point gained. If the sweet-potato weevil does become abundant in any locality, probably the best solution of the difficulty for the Hawaiians will be the substitution of some other crop, as the banana, dry-land taro, or upland rice.

THE MELON FLY.

(*Dacus cucurbitæ.*)

Until the winter months of 1898 all cucurbits (watermelons, muskmelons, squashes, pumpkins, cucumbers, etc.) could be grown in Hawaii in abundance and with comparative ease. From that time the increase of an introduced enemy, an insect pest that has come to be known locally as the melon fly, has all but stopped the growing of these products. Mr. B. O. Clark states that he was growing melons at Pearl City, Oahu, at that time and first noticed the fly in the summer of 1897, and that the pest increased to such an extent by the winter months of 1898 and 1899 that attempts to grow melons were given up after those years.

From 1899 to 1903 watermelons and muskmelons, previously very profitable crops, were not grown to any extent. For several seasons past, however, the production of these crops has been on the increase. The reason for this is undoubtedly the persistence of the Japanese growers in protecting their melons from the flies at or immediately after the setting of the fruit. From observations made during the year the writer is of the opinion that watermelons at least can be grown at a good profit.

The first record of the food plants and injury of the melon fly were made in 1898 by Mr. B. O. Clark, then commissioner of agriculture of the local government. The remedies that Mr. Clark suggested at that time, namely, the covering of the infested fruit and vines and the destruction of the infested melons, are today the most effective measures employed against the pest. The reference is as follows:[b]

> The following letter from Mr. Swain makes inquiry about one of the most serious pests on these islands. The reply may interest others:

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[a] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 6, 1893, p. 44.

[b] Official Bulletin of the Bureau of Agriculture. The Hawaiian, Vol. I, No. 27, p. 6. Honolulu, 1898.

"LAUPAHOEHOE, *August 8, 1898.*

"Professor KOEBELE, *Honolulu.*

"DEAR SIR: We have a new pest that has lately come here in the shape of a fly like a yellowjacket, only not so large. It punctures pumpkins, squashes, beans, tomatoes, watermelons, and all other plants of this nature. It lays eggs inside, which form maggots like the samples I send you. You can judge of their work where the things are growing. Can you suggest any remedy? I send you some samples of their work by the S. S. *Kinau.*

"Yours, truly,

"L. C. SWAIN."

"HONOLULU, *August 11, 1898.*

"L. C. SWAIN, Esq., *Laupahoehoe, Hawaii.*

"DEAR SIR: Yours of the 8th instant at hand and contents noted. Professor Koebele is now in the States, but as I have personal experience with the fly you mention and consulted with Professor Koebele in regard to it, I can state he told me of no remedy except covering the vines, and of course this is not at all practicable except for a few vines in a garden. I tried a spray of whale-oil soap, thinking the odor might keep the fly away, but it did not. I shall try a Paris green solution, 1 pound to 200 gallons of water, keeping it stirred frequently, and apply with a spray pump. This will kill the eggs and young larvæ of the codling moth on apple and other fruits, and possibly may do so in this case. The great difficulty in this climate is that frequent showers wash off the poison, and it has to be repeated frequently. The Paris green can also be applied as a powder, mixed with flour or air-slaked lime, in the proportion of 1 part of Paris green to 100 of flour or lime. I would advise collecting all infected squashes and feeding to pigs or other animals or bury them so deep the fly can not get out when it hatches. If all who grow the crops which it breeds in would do so, I think it could be at least checked; the great difficulty would be to know if there is any wild fruit, etc., upon which it deposits its eggs for development. I have not observed it attacking anything but the cucumber, melon, and squash family.

"The following life history, which I have learned by experimenting in a 'hatchery,' may interest you, if you have not already determined the same for yourself. The fly which you describe is more like a small-sized botfly than a wasp, and will be seen hovering about the vines of muskmelons, squashes, etc., and when disturbed darts away very quickly, so rapid, in fact, one can scarcely follow it with the eye. It stings not only the fruit with its ovipositor, but also the young and tender growth of the vines, depositing a number of eggs, which soon hatch into small white maggots that feed on the tissues of the plant or fruit, causing it to decay. After the maggot has attained its growth, it descends into the soil, where it develops into a small chrysalis of a light yellowish-brown color, and in about ten or twelve days comes out a perfect insect, ready to repeat its mission of destruction. I do not know how many generations it will produce in a year, but in the warmer and drier districts I believe it will breed the year through, except possibly a while during the winter months, and then its development is only retarded by the cooler weather, which prevents the chrysalis maturing so rapidly.

"If you will take a squash or other specimen with the eggs or young maggots in the same, placing it in a box containing two or three inches of loose, dry soil, keeping it covered with a piece of glass, you can soon learn for yourself its life history, and perhaps make observations that may lead to means of successfully combating the pest.

"Yours, respectfully,

"BYRON O. CLARK,
"*Secretary and Commissioner of Agriculture.*"

The melon fly belongs to the family Trypetidæ and was described as new to science in 1899 by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture. Mr. Coquillett's description is as follows:[a]

A NEW TRYPETID FROM HAWAII.

Dacus curcurbitæ n. sp. Head light yellow, the occiput, except the sides and upper margin, reddish yellow, an ocellar black dot, front marked with a brown spot in front of its center and with three pairs of orbital brown dots, a black spot on each side of the face near the middle and a brown spot on the middle of each cheek; antennæ, palpi, and proboscis yellow, the latter mottled with brown. Thorax reddish yellow, the humeri, a median vitta on the posterior half of the mesonotum, another on each side above the insertion of the wings, uniting with an irregular band which extends upon the pleura to the upper part of the sternopleura, also a large spot on each side of the metanotum, encroaching upon the hypopleura, light yellow; scutellum, except its extreme base, light yellow, bearing two bristles. Abdomen light yellow on first two segments, reddish yellow on the others, the extreme base, a fascia at the bases of the second and third segments, usually a lateral spot on the fourth and fifth, also a dorsal vitta on the last three segments, blackish or brownish; first segment of the ovipositor of the female slightly longer than the fifth segment of the abdomen. Wings hyaline, the apex of the subcostal cell from a short distance in front of the apex of the auxiliary vein, the marginal and submarginal cells, the median third of the first basal cell and a large spot in upper outer corner of the first posterior cell, brown; anal cell brown, this color encroaching on the third posterior cell and bordering the sixth vein almost to its apex; posterior crossvein bordered with brown, this color extending to the hind margin of the wing; upper end of the small crossvein also bordered with brown. Halteres light yellow. Legs light yellow, the broad apices of the femora and the last four joints of the tarsi reddish yellow, hind tibiæ reddish yellow or dark brown. Length 6 to 8 mm.

Honolulu, Hawaii. Two males and two females bred by Mr. George Compere from the larvæ living in green cucumbers. Type No. 4207, U. S. Nat. Museum.

The food plants are, locally, all the members of the plant family Cucurbitaceæ (watermelons, muskmelons, cucumbers, squashes, pumpkins, etc., including a wild cucurbit, *Sycos* sp.); pods of beans; tomatoes; and the fly has been reported as infesting ripe fallen mangoes and the fruit of the papaya. Mr. F. W. Terry informs the writer that he bred *Dacus cucurbitæ* from larvæ infesting ripe mangoes during August, 1907.

The life history (see figure 3), covering a period of about three weeks, is as follows: The female by means of her strong ovipositor pierces the epidermis of the melon, or other host plant or fruit, and prepares just beneath the surface, in the tissue, an egg-chamber into which through the one incision or opening are deposited several eggs, the number varying from only 5 or 6 to as many as 15. A single fly may be responsible for many such incisions and usually "stings"

[a] Ent. News, 10 (1899), No. 5, pp. 129, 130.

the fruit several times. The flies are more active in oviposition in the early morning, remaining quiet during the middle of the day and especially on bright, sunny days hidden in the shelter of the vines or foliage about the field during the heat of the day. Observations on the attack of this pest on watermelons indicate that the very young melons are usually chosen for oviposition, presumably because the rind is more tender and capable of penetration. The larger proportion of the melons are infested from time of setting of the fruit until a size of about 3 inches in length is attained. The writer has visited fields where it has been practically impossible to find a melon of that size that was not egg-infested or contained developing larvæ. Larger melons have been found newly infested, but the incision in the varieties observed was near the more tender stem end. This is speaking only of watermelons. Undoubtedly muskmelons and cu-

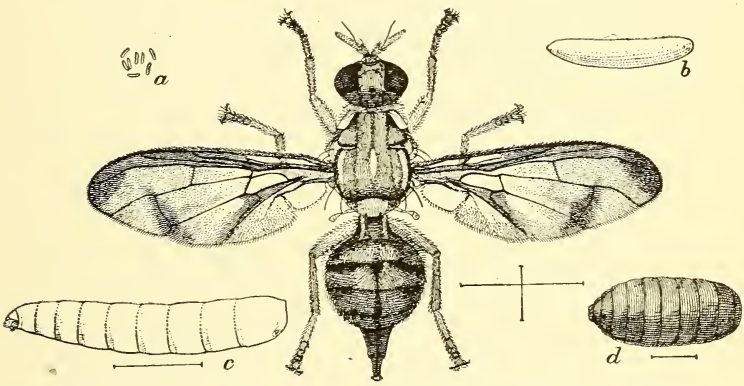

FIG. 3.—Life cycle of the melon fly (*Dacus cucurbitæ*) : *a*, cluster of eggs, natural size; *b*, egg, enlarged; *c*, larva; *d*, puparium. Natural size of adult, larva, and pupa shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

cumbers are capable of becoming infested much later in their development. In a field where the fly is epidemic, however, the larger melons as well contain the larvæ in all stages of development, the melons showing likewise all stages of decay. Since the enemy is an internal feeder, a correct estimate of the damage can not be obtained by a passing observation. Many melons perfect in shape upon being opened are found to be infested and sometimes completely rotted with the exception of the rind. In some instances the attack is resisted and the wound heals over, but the result is a deformed product, unfit for the market.

The vines as well as the fruit are infested. This is especially true if the growth is succulent. The vines are usually infested in the larger portions near the crown. During wet weather the decay of the fruit and vines progresses more rapidly than during dry

weather. In dry seasons the vines as a rule survive the attack and the wounded portions heal over.

After hatching from the egg the larvæ burrow on into the tissue of the melon, feeding entirely on the interior. When removed from the melon the larvæ have a peculiar mode of locomotion or possibly of protection. They double themselves together and then, suddenly straightening out, throw themselves into the air and quite a distance from the place they occupied. When fully developed the larvæ leave the infested melon or vine and enter the soil directly beneath, where at a distance of an inch or so from the surface they pupate.

No special natural enemies or checks to the melon fly have been observed in Hawaii. Regarding natural enemies Mr. Alexander Craw, superintendent of the division of entomology, board of agriculture and forestry, Hawaii, says:

> From dead specimens of the "melon fly" (*Dacus cucurbitæ*) received by this division from the government entomologists of India, we learn of the existence of several parasites that prevent its seldom or ever becoming a pest there. An effort should be made to introduce these parasites here by way of Hongkong. This would be a difficult experiment, owing to the great distance, but the undoubted benefit to the melon industry of this Territory, in case these parasites were successfully introduced and established, would justify the expenditure of considerable money in the attempt to control this pest.[a]

Prof. W. W. Froggatt, government entomologist of New South Wales, who is making an official trip around the world, recently visited Hawaii. One of the principal objects of his mission was in the interests of controlling the Queensland fruit fly (*Dacus tryoni*), a fly belonging to the same genus as our melon fly. Mr. Froggatt, in company with the writer, visited several districts in these islands where melons were growing, and detailed information on the fly and its occurrence in Hawaii were obtained by him. The writer is pleased to say that Mr. Froggatt will visit the countries of the Mediterranean and India before his return to Australia, and will carefully investigate any enemies of fruit flies in general that occur in those countries. If any special enemies of the group of flies to which our melon fly and the Queensland fruit fly belong are found they will be introduced and established in Australia and it will then be a comparatively easy matter to introduce them from that country into Hawaii. Mr. Froggatt is kindly keeping the writer informed of the progress of his trip, and much of interest to Hawaii will undoubtedly result.

The common preventive measure among the Japanese growers is to cover the young melons with a piece of gunny sack, paper, or some straw as soon as they set. When the melons have outgrown the protection of this covering, they are usually beyond the danger of an attack by the fly. It requires constant attention to cover the newly

[a] Hawaiian Forester and Agr., 4 (1907), No. 5, p. 113.

set melons before they are visited by the overindustrious fly. Protection could be secured by hand pollinating the flowers and covering them before the fruit is formed. There is a difference in the resistance of the different varieties of melons. The harder skinned varieties are less subject to injury, and it is well to select a hard-skinned melon for planting, even at a sacrifice of quality.

All infested melons and vines should be collected at regular intervals throughout the growth of the crop and either burned or buried. Burning is the most effective, but if the acreage is large, holes or pits can be dug at convenient distances through the field and all infested melons and vines collected at intervals of five or six days and deposited in the nearest pit. They should then be covered with earth to a depth of several inches. Overirrigation, producing succulent growth, favors infection of the vines.

After harvesting a crop all melons and vines left in the field should be collected and destroyed. If not done this refuse will breed swarms of the fly that will seek the products they infest in the surrounding district.

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FLEAS.

Several outbreaks of fleas have occurred in Honolulu during the year. The writer dealt with two cases in residences and succeeded in controlling the pests. In each instance the species was the common dog and cat flea (*Ctenocephalus canis*).[a] The determination is by Mr.

[a] *Pulex serraticeps* is a synonym.

D. W. Coquillett, Bureau of Entomology, U. S. Department of Agriculture.

Mr. C. F. Baker gives the following in regard to the distribution and hosts of this species:

> The common cat and dog flea is probably the most widely distributed member of the order, occurring practically wherever cats and dogs occur. Doctor Lutz sends specimens from Brazil. It seems to be a normal and abundant parasite of cats and dogs, but has been found on a variety of other animals. It occurs commonly as a transient guest on almost all of the domesticated, semidomesticated, or caged animals, and will bite human beings whenever opportunity offers. Many reported cases of infestation of houses have been found to be due to this species, rather than to *Pulex irritans*. The case of a lot of fleas collected by Mr. Snyder from a fox at San Diego, Cal., offers a peculiar instance of unusual occurrence. A part of this lot proved to be *P. irritans* and the rest this species.[a]

The source of the fleas was traced to dogs about the dwellings, in one instance to homeless dogs that had taken up their abode beneath the house, and in the other to a dog belonging to the caretaker of the place. In the latter case when the family returned, after a considerable absence, they found the house, yard, and outbuildings infested with fleas. In and about Honolulu there are numbers of homeless dogs and cats that breed and distribute the pest wherever they roam.

Briefly the life cycle of the dog and cat flea is as follows: The eggs are laid loosely on the hairs of the dog or cat. These animals, when lying or walking around the place, leave behind innumerable eggs that become detached with the hairs in the persistent efforts of the animals to dislodge the adult fleas that are feeding on them. The eggs hatch and the larvæ develop in any place where the conditions of temperature and moisture are favorable. They feed during the larval period of life on whatever organic matter may be found in the places they occupy. These places may be in or beneath a rug or carpet in a house, in the dust of an unswept room, in crevices or joints of the underpinnings of the house, in the lawn beneath the grass, or in any of the outbuildings where the animals sleep.

In regard to the length of time necessary for development, Doctor Howard says:

> In the observations made at this Department upon this species of flea during the summer of 1895, some difficulty was found in preserving just the right degree of moisture to enable the insect successfully to transform. An excess of moisture was found prejudicial to the development of the species, as was too great dryness. The observations showed, however, that at Washington in summer an entire generation may develop in a little more than a fortnight. Hence

[a] A Revision of American Siphonaptera. Proc. U. S. Nat. Museum, 27 (1904), p. 384.

a housekeeper shutting up her house in June, for example, with a colony of fleas too small to be noticed inside it, need not be surprised to find the establishment overrun when she opens it up again in September or October.[a]

The following remedial measures were recommended:

(1) If the lawn is infested, cut the grass as close to the ground as possible and burn the refuse. Exposure to the air and sun will be detrimental to the development of the larvæ. Keep the lawn well watered.

(2) Clean out and burn all refuse from beneath the infested dwelling, leaving the surface of the ground as bare as possible, and apply an even dressing over the surface of lime, sulphur, and buhach at the rate of 20 pounds of air-slaked lime to 3 pounds of powdered sulphur and 1 pound of buhach, thoroughly mixed and dry. Spray the underpinnings of the house, and the drives and walks (if the latter are sand, gravel, or dirt), with kerosene emulsion at the rate of 1 part of stock solution of the emulsion to 10 parts of water.

(3) If dogs are owned, provide a room for them to sleep in and keep cats out of the house. Wash with strong, hot soapsuds the floors of the room where the dogs are to sleep, and sprinkle afterwards, when dry, with a liberal amount of buhach. Use a liberal amount of buhach in places where the dogs have been in the habit of sleeping and remove and burn from such places all refuse, old sacks, matting, etc. Every week or so take the dogs to the room provided for them and brush them thoroughly with a strong stiff brush. Afterwards collect the resulting hairs and the bedding and burn or immerse the sacks in hot soapsuds and hang in the sun to dry. Then wash the room out as before and sprinkle with buhach and return the bedding. The dogs should be washed regularly, a little creolin being added to the water.

(4) If the house is infested, sprinkle a liberal amount of buhach beneath all rugs and matting and under all shelving and cabinets. The following day take all rugs, carpets, and matting out of doors and shake thoroughly and hang in the sun for several hours. Wash the floors with hot soapsuds. Sprinkle buhach beneath the rugs, carpets, and matting when returning them to the house.

In one case treated the fleas were so numerous that the men engaged in the work of destruction were with difficulty held to their job. Finally in desperation the writer purchased a quantity of "fly-paper" and wrapped the legs of the laborers in this (sticky side out). Several thousand adult fleas were captured in this manner in a day's work, and the workmen were thus afforded a measure of protection.

[a] U. S. Dept. Agr., Div. Ent. Circ. 13. 2. ser., 1896, p. 4.

MOSQUITOES.

The top-minnows[a] introduced in 1905 to feed upon mosquito larvæ are established on all the principal islands. Areas of standing water are common in Hawaii and breed mosquitoes in immense numbers. (See Pl. I, fig. 1.) The following distribution of the fish has been made: Island of Oahu—Honolulu and vicinity generally, Aiea, Pearl City, Waialua, Maunawai, Wahiawa, and Waimanalo; island of Hawaii—Hilo and vicinity, and Paauhau; island of Maui—Kahului, Wailuku, and Lahaina; island of Kauai—Lihue, Eleele, and Waimea; and island of Molokai—Kalaupapa.

The history of the introduction of these fish has been summed up by the writer and published as Press Bulletin No. 20 of this station. It will be no longer necessary to breed the top-minnows for distribution, as the little fish swarm in several places where they have been liberated and can be obtained easily by those desiring to extend their distribution. This project is therefore completed. Hawaii has gained an addition to its fauna that will in future years many times repay the sum expended in the introduction and establishment of these natural enemies of mosquitoes.

The common Hawaiian mosquito, locally known as the "night" mosquito, previously reported by the writer as *Culex pipiens*[b] and by Mr. F. W. Terry as *C. fatigans*,[c] has been determined by Dr. H. G. Dyar as *C. cubensis*. One point of interest in regard to this species observed during the year is worthy of record. The larvæ have been found to breed in brackish water. To what extent can not be said without a careful survey. Waimanalo on the windward side of the island of Oahu has long been notorious as a mosquito-ridden place, and this is saying quite a little in Hawaii, where mosquitoes have been generally abundant. The main source of the mosquitoes was traced to a makai marsh, and an analysis of a sample of water from this marsh, taken at a place where mosquitoes of this species were breeding in immense numbers, gave 50 grains of salt to the gallon. (See Pl. I, fig. 2.)

In 1904 the writer pointed out the danger from yellow fever attending the establishment of a direct line of steamers between Hawaii and the Mexican coast and Panama.[d] The present discussion of this subject and its importance to the welfare of Hawaii leads the writer

[a] The species introduced were *Mollicnsia latipinna*, *Fundulus grandis*, and *Gambusia affinis* of the family Pœciliidæ. These fish were collected and transported to Hawaii from Seabrook, near Galveston, Tex., by Mr. Alvin Seale.

[b] Hawaii Expt. Sta. Bul. 6, 1904, pp. 14–21.

[c] A Preliminary Account of the Insects of Economic Importance in the Hawaiian Islands (Diptera). Hawaiian Forester and Agr., 3 (1906), No. 2, pp. 36, 37.

[d] Hawaii Expt. Sta. Bul. 6, 1904, pp. 22, 23.

FIG. 1.—STANDING WATER FROM RICE AND TARO FIELDS WHERE MINNOWS HAVE BEEN SUCCESSFULLY INTRODUCED.

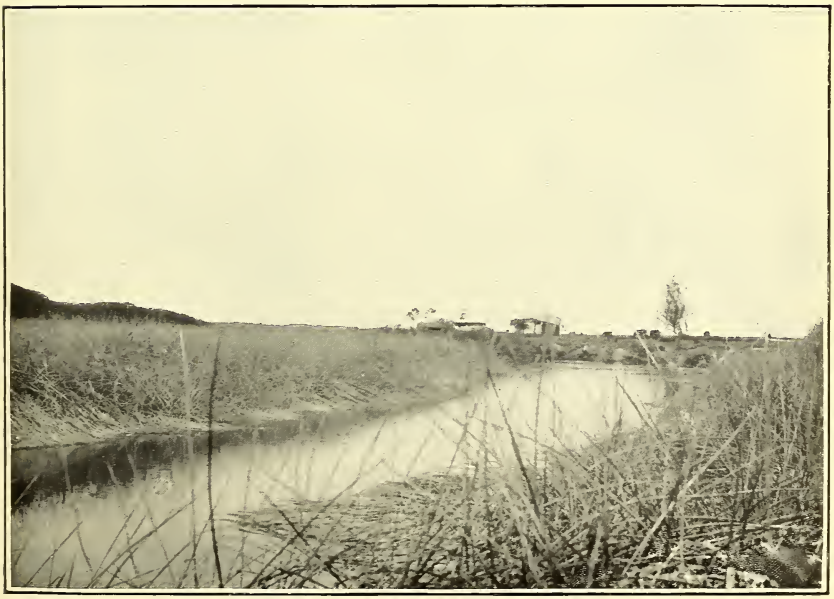


FIG. 2.—MARSH AT WAIMANALO, ON WINDWARD SIDE OF OAHU, WHERE FORMERLY MOSQUITOES BRED ABUNDANTLY.

to reprint here an article by Prof. V. L. Kellogg. The article is as follows:

To the Editor of Science: The continuous discussion of Panama Canal affairs suggests to me to call attention to the possibility that the cutting of the canal may lead to trouble from yellow fever in two of our Pacific island colonies. In the summer of 1902, spent in the Hawaiian and Samoan Islands as agent of the U. S. Bureau of Fisheries, my attention was forcibly called to the unusual proportions of the mosquito plague in both these island groups. If it were not for the dragon flies which wage effective war against the "day mosquitoes," and for the bed canopies of netting which protect the sleeper from "night mosquitoes," life would hardly be tolerable in Honolulu. In Tutuila (our principal Samoan island) mosquitoes are the most obvious features of the above-water fauna aside from the brown natives themselves. Now both in Hawaii and Samoa one of the most abundant of the infesting mosquito species is *Stegomyia fasciata*, which is none other than the yellow-fever mosquito, that is, the particular mosquito species which harbors and disseminates, in yellow fever regions, the plasmodium or bacterium which is the immediate cause of the disease.

So far no cases of yellow fever have occurred in Hawaii or Samoa, but this is obviously not because of the absence of the yellow fever host, but, presumably, of the yellow fever specific causal agent, the pathogenic "germ." It is to be presumed that ships have not as yet carried yellow-fever-germ-infested specimens of Stegomyia from the West Indies to Hawaii or Samoa. Going around the Horn is probably an effective check to the spread of yellow fever from the West Indies to our Pacific Islands by reason both of the time required and the low temperatures met. Besides, there is little traffic now between the two regions. But with the cutting of the canal, making possible a direct short-time passage of ships from the Gulf of Mexico to Hawaii, or to Samoa, all of the voyage being within tropical or subtropical latitudes—the Hawaiian Islands are in 20° north latitude, the Samoan Islands in 14° south latitude—will there not be a real danger of planting the dread agent of yellow fever in our Pacific colonies in which already the necessary insect host exists in enormous numbers? There may be obvious reasons why this migration can not take place, but they are not apparent to me now. It is, at least, a contingency to be had in mind by those charged with the responsibility of public health affairs in Hawaii and Samoa.[a]

BEE KEEPING.

The principal line of work in bee keeping during the year has been the continuation and completion of the work on the source and characteristics of Hawaiian honeys, the assistant chemist of the station cooperating in a determination of the chemical composition of the same. This information has been prepared for publication as Bulletin No. 17 of this station. In all 54 samples of honey were collected and the source in each instance determined. Forty-nine of these samples were analyzed and a detailed study made of the two types represented—a floral honey and a honeydew honey.

The greatest value of this work has been its relation to marketing the Hawaiian product under the Federal Food and Drugs Act of June

[a] Science, n. ser., 23 (1906), No. 577, p. 114.

30, 1906. The bulk of the Hawaiian honey is of a type that has been little studied and, for this reason, was not considered in the official definition of honey. The type is decidedly abnormal under the present official definition of honey and its abnormal characteristics are due to the presence of honeydew, a saccharine substance secreted by certain leaf-sucking insects or secreted by the plant itself from special organs. In Hawaii the honeydew is derived by the honeybee mainly from the secretions of the sugar-cane leaf hopper and the sugar-cane aphis on the leaves of the sugar cane.

The problem confronting the Hawaiian bee keepers was presented by the writer in person to the proper officials at Washington. While no modification of the official standard of honey was obtained, the results of the investigations on the Hawaiian product by this station have been accepted by the experts having the work in charge as satisfactory and conclusive.

The Hawaiian honeys, while somewhat abnormal in their ash content, are recognized as natural products and are not considered as adulterated in the usual meaning of that term. All honeys that polarize to the left, and this includes the pure algeroba honey and many of those made by bees from floral nectar and other substances, will be recognized as pure natural products and may be marketed as such. Those that polarize to the right are to be given a distinctive label, and as they are largely composed of honeydew, it is suggested that they be labeled "honeydew honey." A statement can accompany the label on the honeydew package which may read as follows: "This is a natural product containing no added glucose or other added sugars. It is unadulterated and is a product gathered and stored by the honeybee."

The writer would here express his appreciation of the careful and detailed consideration given the subject during his stay in Washington by Dr. E. F. Phillips, in charge of apicultural investigations, Bureau of Entomology, and Dr. C. A. Browne, in charge of the sugar laboratory, Bureau of Chemistry.

Two further projects relating to bee keeping have developed from the work on Hawaiian honey. They are (1) the introduction and establishment of bee plants to increase the floral product and improve the character of Hawaiian honey, and (2) the production of beeswax on a commercial scale. The writer spent two weeks in southern California on his return home from Washington and gave special attention to plants desirable to introduce into Hawaii for bee pasturage. White sage, black sage, two species of Phacelia and horehound, abundant nectar producers and suitable for dry waste lands, will be introduced during the coming year. A list of some twenty other plants was obtained and other introductions will be made. Some of the plants are valuable as forage, but others must be studied to learn

whether or not there will be danger of their invading the pasture lands or cultivated areas. As regards wax production, wax is at present considered simply incidental to honey production. The writer believes it will be more profitable to Hawaiian bee keepers to increase the proportion of wax to honey and experiments will be undertaken with this in view. The experiments will include the feeding back of honey and modifications of the present methods of extraction and the use of foundation.

FOUL BROOD.

Neither European foul brood (*Bacillus alvei*) nor American foul brood (*B. larvæ*) has as yet become established in Hawaii. In order to prevent their introduction the Hawaiian Bee Keepers' Association was successful in obtaining the following legislation at the last session of the Territorial legislature:

AN ACT (ACT 69) To amend Chapter 28 of the Revised Laws of Hawaii by adding to said chapter a section to be known as Section 389A.

Be it enacted by the legislature of the Territory of Hawaii:

SECTION 1. Chapter 28 of the Revised Laws of Hawaii is hereby amended by adding a new section thereto to be known as Section 389A, and to read as follows:

"SECTION 389A. It shall be the duty of the board to make rules and regulations and to amend the same from time to time, in its discretion, subject to the approval of the governor, for and concerning the importation into the Territory of bees and for the preservation, protection, and improvement of bees now within the Territory, and for the quarantine, inspection, fumigation, disinfection, exclusion, or destruction, either upon importation into the Territory or at any time or place within the Territory, of any bees, and any box or other container and their contents in which bees have been imported or contained, which is or may be infested with or liable to assist in the transmission or dissemination of any insect or disease injurious to bees. All rules and regulations made as aforesaid shall have the force and effect of law. It shall be the duty of the board to establish an observational apiary, and all bees imported into the Territory shall be there quarantined, free of cost to the owners, until such time shall have elapsed as to enable the proper entomologist or inspector of the board to certify to the owners that such bees are clean and free from disease. The entomologists or inspectors of the board may enter upon the premises of any bee keeper for the purpose of inspecting the apiaries and of carrying out the orders of the board, and they shall not be holden guilty of any misdemeanor by so doing nor shall they be personally liable in damages, except for acts beyond the scope of their authority or due to their own negligence."

SEC. 2. This act shall take effect from and after the date of its approval.

Approved this 17th day of April, A. D. 1907.

G. R. CARTER,
Governor of the Territory of Hawaii.

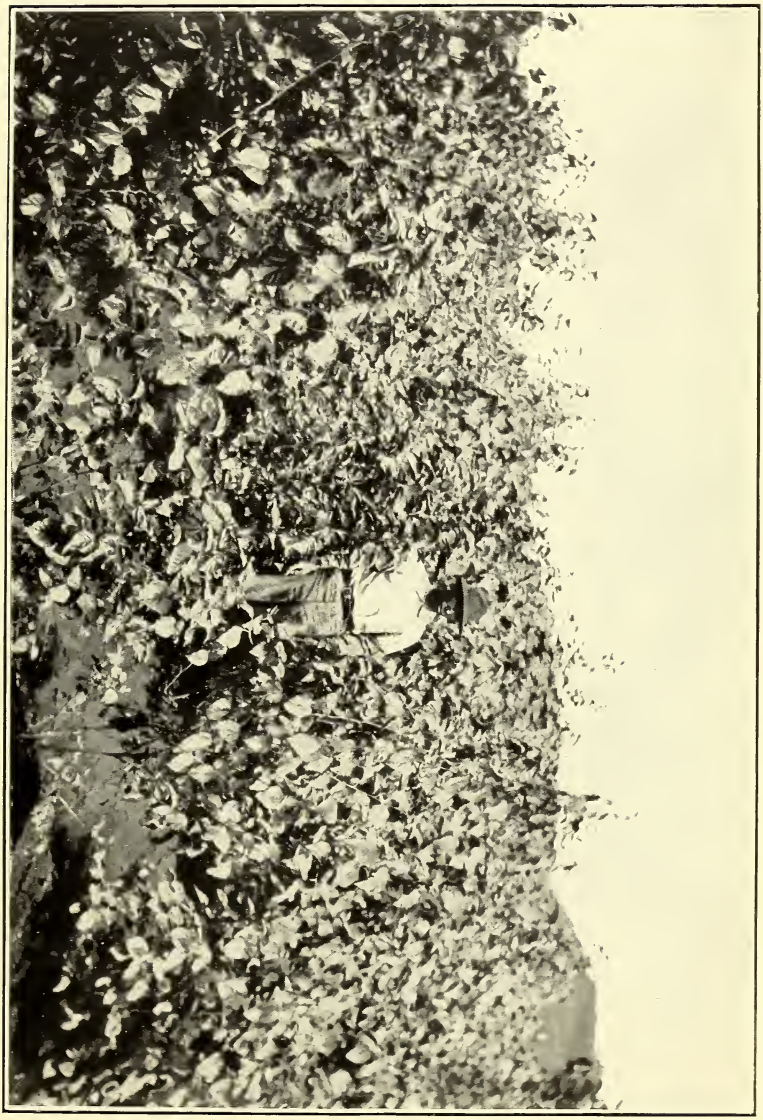
SILK CULTURE.

The investigations relating to the possibility of silk culture have progressed far enough to enable the writer to state definitely that silk of good quality can be produced with as little effort in Hawaii

as in any silk-producing country. Three crops of cocoons have been grown, the details of which are given in the reports of the entomologist for 1905 and 1906, representing the Japanese white, the Chinese Oro yellow, and the Italian Sferici races, and these cocoons have been pronounced by the experts of the U. S. Department of Agriculture Bureau of Entomology "well worthy of being graded as first class." Doctor Howard also states that the economy in reeling "is equal to the most economical results obtained in experienced silk-producing countries." These results were obtained under abnormal and adverse conditions of food and equipment for growing the worms.

The 1906 experiments were all but ruined by a shortage of food at the most critical time, due to a drought that forced the mulberry trees into a semidormant state. The supply of mulberry leaves has heretofore been obtained from various trees and hedges growing in widely separated places in the city of Honolulu. To provide for future experiments and to obtain information on the culture of the mulberry for silk raising, a mulberry plantation has been established during the year. (See Pl. II.) This plantation is about 1 acre in extent, is provided with facilities and water for irrigation, and consists of 2,000 seedlings of *Morus alba*, received through Dr. L. O. Howard from the Bureau of Plant Industry.

Two systems of planting the mulberry have been tried. The seedlings were placed in orchard rows and in hedges. The plants in orchard rows will be allowed to grow to trees and will be pruned to produce the maximum amount of leaves. The hedges will be stripped of their leaves during feeding time and cut back after each picking. The extent that leaf production can be influenced by methods of culture and irrigation will be determined, together with the most profitable system of mulberry culture as regards labor for leaf picking. The project on silk culture will be limited during the coming year to the culture of the mulberry. The next experiment on the growing of cocoons will be undertaken on a more extended scale than heretofore; the abundant food supply close at hand will make this possible. If Hawaii is to succeed in holding the laboring class to the soil, the industry of silk culture is worthy of receiving serious consideration.



MULBERRY SEEDLINGS TEN MONTHS FROM TIME OF PLANTING.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 4.

(Continued from the Annual Report of the Hawaii Agricultural Experiment Station for 1906.)

FIELD CROPS.

RICE.

A beetle (*Rhizopertha pusilla*) was bred from stored rice that has been introduced for seed. This species is recorded by Blackburn from the island of Oahu in 1885.[a]

The Angoumois grain moth (*Sitotroga cerealella*) has been bred in large numbers from stored rice during the past year. The moth infests both harvested rice and standing rice in the field. The pest has proved especially persistent in stored rice in the paddy, but has been successfully controlled at the station by carbon bisulphid. The fact that this pest can breed uninterruptedly throughout the year in Hawaii will necessitate prompt remedial measures when infestation occurs to prevent a heavy loss in weight.

In regard to a remedy, Chittenden says:[b]

> A limited number of insects, like the Angoumois grain moth in the extreme South, enter the grain in the field, and certain precautions are therefore necessary to prevent their access to the granary. This is accomplished (1) by harvesting as soon as the grain is ripe, and (2) by thrashing as soon afterwards as possible.
>
> In the process of thrashing or cleaning much infested grain is blown out with the chaff and dust, and the moths are killed by the agitation which the grain receives; but the immature forms of these insects, concealed in the kernels as eggs, larvæ, and pupæ, are apt to survive this treatment, and further measures are necessary for their destruction.
>
> For this purpose a quarantine bin is desirable, to be as nearly air-tight as possible, in which the newly thrashed as well as the infested or suspected grain can be fumigated with bisulphid of carbon. * * *
>
> Fresh grain should not be exposed to insect attack by being placed in bins with "weeviled" grain, or even housed under the same roof with such grain. If before storing in buildings that have been infested the old grain be removed, the bins thoroughly cleaned, floors, walls, and ceilings brushed and scrubbed, the chances of infestation will be reduced to a minimum. If the storehouse has been badly infested a fumigation with bisulphid is necessary.

SWEET POTATO.

The sweet-potato weevil (*Cylas formicarius*). (See pages 28–30.)

The sweet-potato sphinx moth (*Protoparce cingulata*). The caterpillar of this moth (*Sphinx convolvuli*) is recorded by Meyrick, in Fauna Hawaiiensis, in 1899, from the islands of Hawaii and Maui.

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[a] The determinations of the Coleoptera (beetles) recorded in this report were made by Mr. E. A. Schwarz, of the Bureau of Entomology, U. S. Department of Agriculture.

[b] U. S. Dept. Agr., Farmers' Bul. 45, pp. 19, 20.

The writer has collected specimens from the islands of Oahu and Molokai. The caterpillars are common on sweet-potato vines and *Ipomœa* spp.

The sweet-potato vine borer (*Omphisa anastomosalis*). The writer has not observed the work of this moth, but the species is recorded by Meyrick in Fauna Hawaiiensis in 1904. Mr. O. H. Swezey has observed the moth and the work of the caterpillars in sweet-potato vines and records his observations as follows:

> This Indo-Malayan moth was first recorded for Honolulu in 1904. Since then it has no doubt been on the increase, and may possibly before long become a garden pest, if not so already. During January, February, and March, 1906, I found the larvæ boring in vines of sweet potato in my garden. Of about half a dozen hills, all were found to be infested. The larvæ were found boring in the vines near the base, and hence just at the place to be the most injurious. Often two or more near together in the same vine, living upon the green, juicy pith of the stem. They probably do considerable boring in the potatoes also, as one was found in a potato from the market.[a]

The root maggot (*Pegomya fusciceps*) was collected on the island of Molokai during March, 1907. This insect pest is known commonly under various names, as the seed-corn maggot, the cabbage-root maggot, etc. Chittenden records the species as a pest of sweet potatoes.[b]

FRUIT CROPS.

PINEAPPLE.

The common mealy bug (*Pseudococcus citri*)[c] was recorded in the writer's report for 1904 as *Dactylopius* sp. The species is recorded by Kirkaldy in Fauna Hawaiiensis in 1902 from orange.

The pomace fly (*Drosophila ampelophila*). The determination of this fly was made by Mr. D. W. Coquillett, of the Bureau of Entomology, from specimens collected by the writer on July 19, 1906, found developing in ripe pineapples in canneries at Wahiawa, Oahu. This fly is common throughout the United States and particularly noticeable in the fall of the year about cider mills and wineries, about which it breeds in the pomace and refuse. No evidence of the work of the fly could be found in the field and apparently its injury is confined to the overripe and bruised pineapples in the cannery. Destruction of the waste about the cannery is an effective method of control.

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[a] Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 76.

[b] U. S. Dept. Agr., Div. Ent. Bul. 43, 1903, p. 69.

[c] The determinations of the Coccidæ (scale insects) recorded in this report were made by Mr. J. G. Sanders, Bureau of Entomology, U. S. Department of Agriculture.

MANGO.

Trionymus americanus, a small mealy-bug-like coccid, was collected from the bark of the Bombay mango by Mr. Donald McIntyre at Moanalua, Oahu, during July, 1906.

Thrips (Thripidæ, undetermined). Thrips were first noticed on the leaves of mangoes during 1906 at Moanalua, Oahu. During the summer of 1907 the insect had increased to injurious numbers in this locality and specimens were recently collected and referred to the Bureau of Entomology for identification. The insect is causing serious injury to the young growth of the trees and on badly infested trees blemishes the surface of the developing fruit. The most effective remedy thus far has proved to be a spraying mixture of whale-oil soap and tobacco prepared as follows: Five pounds of waste tobacco was boiled in sufficient water to make about 1 gallon of strong decoction. Two pounds of whale-oil soap was dissolved in 1 gallon of boiling water and then mixed with the tobacco decoction. The mixture was diluted with 10 gallons of water and applied as a spray.

APPLE.

The following insects have been collected from apple trees: The Japanese beetle (*Adoretus umbrosus tenuimaculatus*) and the scale insect (*Pseudaonidia clavigera*), collected in September, 1906, from apple at Koloa, Kauai.

ORANGE.

The scale *Parlatoria ziziphus* was taken from orange in January, 1907.

BANANA.

The banana leaf-roller was recorded in the 1904 report of the writer as *Omiodes blackburni*. Mr. O. H. Swezey, in a recent bulletin of the Hawaiian Sugar Planters' Experiment Station,[a] distinguishes the species infesting the banana from the common *O. blackburni* found on palms and describes the species infesting the banana as new under the name of *O. meyricki*.

COCOANUT.

The following insects have been observed working on the cocoanut palm tree: The cane borer (*Sphenophorus obscurus*), the palm leaf-roller (*Omiodes blackburni*), and the Florida red scale (*Chrysomphalus ficus*).

[a] Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 5, pp. 24–27. (August, 1907.)

ORNAMENTAL PLANTS.

HIBISCUS.

Cosmophila sabulifera. The caterpillars of this moth were destructive to the foliage of hibiscus about Honolulu in one or two instances during the year. The moth was determined by Doctor Dyar, of the U. S. National Museum. The species is recorded by Meyrick in 1899 in Fauna Hawaiiensis, from Hawaii, Kauai, and Oahu.

PEPPER TREE.

The following scale insects have been collected during the year from the pepper tree: *Saissetia nigra* and *Aspidiotus lataniæ.*

ROSE.

The common aphis of the rose in Hawaii has been determined and recorded during the year as *Macrosiphum rosæ* by Mr. Kirkaldy.[a]

BAMBOO.

A scale insect (*Asterolecanium miliaris*) was collected from bamboo on Kauai in October, 1906.

FOREST TREES.

RUBBER (CEARA).

The following scale insects were collected from Ceara rubber during the year: *Aspidiotus cyanophylli* and *Saissetia oleæ.*

Wireworms, larvæ of a click beetle (Elateridæ, undetermined), did some damage to seeds in seed beds in Nahiku, Maui, at the beginning of the planting there. The seeds had been filed through at the ends, allowing entrance by the worms. The source of the wireworms was found to be horse manure used in preparing the seed beds, the manure offering a breeding place to the beetles.

A bark beetle (*Xyleborus affinis*) and a snout beetle (*Pseudolus longulus*) were found to infest this tree, their attack being in the unhealed wounds caused by repeated tapping.

ALGEROBA.

The scale insect (*Asterolecanium pustulans*) was taken during the year from the algeroba on the islands of Oahu, Kauai, and Molokai.

WILD GUAVA (WAIAWI).

A bark beetle (*Xyleborus affinis*), Kauai, and the scale insect (*Aspidiotus lataniæ*), also from Kauai.

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[a] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 100.

LIVE STOCK.

A considerable portion of the writer's time during the latter part of the year has been occupied in a study of the insects affecting live stock in Hawaii. The species affecting live stock that have been observed or are recorded from Hawaii will be briefly listed here, since a detailed report is in course of preparation.

CATTLE.

The horn fly (*Hæmatobia serrata*)[a] was probably introduced during 1897 and first recorded by Koebele in 1899. It also attacks sheep in Hawaii and to some extent horses.

The warble fly and the heel fly, *Hypoderma bovis* and *H. lineata*. One and possibly both of these flies have been brought to Hawaii with imported cattle from the western coast of the mainland. Neither species has apparently become established.

SHEEP.

The blow fly (*Calliphora dux*) occurs on the islands of Hawaii, Kauai, Oahu, and Molokai. This species is the abundant and injurious blow fly of the Hawaiian Islands.

The English bluebottle fly (*Lucilia serricata*). This animal parasite was taken in small numbers in company with the blow fly (*Calliphora dux*).

The American bluebottle fly (*L. cæsar*). This fly is recorded from the island of Hawaii by Grimshaw in Fauna Hawaiiensis in 1901.

The flesh flies (*Sarcophaga barbata* and *S. pallinervis*). Both of these species have been bred from dead animal tissue and would probably attack wounds in live stock.

The sheep bot fly or head maggot (*Œstrus ovis*). Recorded by Grimshaw in Fauna Hawaiiensis in 1901 from the island of Kauai.

The screw worm (*Compsomyia macellaria*). Reported from the island of Niihau during 1905.

HORSES.

The stable fly (*Stomoxys calcitrans*).

The horse bot fly (*Gastrophilus equi*).

The horse chin fly (*G. nasalis*).

The "night" mosquito (*Culex cubensis*).

[a] The determinations of the Diptera (flies) mentioned in this report were made by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture.

POULTRY.

Lice, undetermined.
Mites, undetermined.
The "night" mosquito (*C. cubensis*).

DOGS.

The dog flea (*Ctenocephalus canis*) (see page 35), the dog tick (*Rhipicephalus sanguineus*), and the "night" mosquito (*C. cubensis*).

STORED PRODUCTS.

A beetle (*Silvanus mercator*) was bred during the year from crackers and a prepared "breakfast food."

The ham and cheese maggot (*Piophila casei*) was collected during the year on the island of Molokai.

The cadelle (*Tenebroides mauritanica*) was bred in immense numbers from horse feed (rolled barley) in August, 1907.

A beetle (*Araeocerus fasciculatus*) was bred from the seeds of St. John's bread (*Ceratonia siliqua*) received from Kohala, island of Hawaii. This same beetle was bred from cotton bolls received from Kona, island of Hawaii.

A weevil (*Calandra linearis*) was bred from imported seeds of the sweet tamarind. Blackburn records *C. linearis striata* in 1885 as "plentiful in decaying tamarinds, near Honolulu."

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REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

The chief work of the year in the horticultural division has consisted in experiments in the shipping of tropical fruits. The horticulturist sailed from Honolulu August 1, 1906, accompanying a shipment of fruits composed of pineapples, avocados, papaias, and bananas. Arriving at San Francisco August 7, the whole shipment of fruit, except the bananas, was transferred immediately to express cars and taken to Portland, Oreg. From this point the fruit was distributed to Astoria, Tacoma, Seattle, and Vancouver, British Columbia. The results of these experiments, so far as the possibility of fruit shipping is concerned, and the methods best suited to shipping are embodied in a bulletin of this station.[a] It may be said here, however, that the experiments led to the belief that it is perfectly feasible to ship avocados and papaias to any market on the Pacific coast which can be reached by a direct journey; and pineapples and bananas may be shipped much farther. A large portion of the shipment, even of papaias and avocados, arrived in Portland in good condition, and specimens of each of these were taken to all the points mentioned. Specimen packages of pineapples were successfully shipped from Portland to the governors and the mayors of cities in all the chief mountain States.

The following letter from Governor Gooding, of Idaho, and the excerpt from a letter of Mr. G. B. Dennis, chairman of the publicity committee of the Chamber of Commerce of Spokane, Wash., will indicate something of the condition in which these fruits arrived, and the market which they would find in any part of this region.

State of Idaho, Executive Office,
Boise, Idaho, August 31, 1906.

Jared G. Smith, *Special Agent Hawaii Experiment Station,*
U. S. Department of Agriculture, Honolulu, Hawaii.

My Dear Sir: Your crate of fruit, which you very kindly sent me, was received about two days ago in the very finest possible condition. I want to thank you and the Hawaii promotion committee for your kindness, and to assure you that if you are able to deliver as fine fruit as this there should be no difficulty in securing a market throughout the United States for your product.

I have the honor to remain yours, very truly,

F. R. Gooding, *Governor.*

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[a] Hawaii Sta. Bul. 14.

SPOKANE, WASH., *August 24, 1906.*

MR. JARED G. SMITH,

Special Agent in Charge, Hawaii Experiment Station, Honolulu, T. H.

DEAR SIR: I am the recipient of your twofold compliment—your letter of July 26, and the crate of pineapples received by express the day before, and assure you that I accept the compliments of the Hawaii Experiment Station and the Hawaii promotion committee very gratefully.

The pineapples were received in perfect condition, there not being a single blemish anywhere on any of them. It was my pleasure to eat one of them, and to distribute the other five among the members of my committee, all of whom gave high praise to the delicious taste and flavor of the fruit. I personally have no hesitancy in stating that these features of the fruit, as well as that of size, exceed those of the fruit that we are used to receive here from southern California, Mexico, and Florida, and there should be no reason why the Hawaiian Islands should not command this trade with this northwestern section of the United States.

Very truly yours,

G. B. DENNIS,
Chairman, Publicity Committee, Chamber of Commerce.

The Pacific Northwest is a market which Hawaiian fruit growers should seek to develop. With the direct communication which is bound to come sooner or later this will be one of our nearest markets. It is also the most remote market in the United States from the standpoint of Hawaii's competitors in tropical fruit growing in Florida, the West Indies, and Central America. It is so situated that from these points a long haul by rail is unavoidable. Hawaii even at the present time can reach this market by water route exclusively. The Pacific Northwest has a large and growing population. There is probably no part of the United States which is making as rapid strides in prosperity and in increase of a desirable class of population. The three cities of Portland, Seattle, and Tacoma in themselves represent nearly half a million people of a class that can afford to spend money freely for Hawaiian fruits. The whole surrounding country tributary to these cities is rich in agriculture, lumbering, and other resources, and is destined to become the center of a very large population. The same may be said of Western Canada, toward which the streams of population have been flowing rapidly for several years. Both these great sections of country, while rich in agricultural resources, can not grow either tropical or even subtropical fruits, and therefore offer a most inviting field for the sale of Hawaiian fruits.

This is emphatically the time to get into these markets and gain a foothold before competitors become so firmly established as to make entrance difficult for the Hawaiian growers.

ORCHARD AND OTHER FRUITS.

During the year the orchard area has been increased by the planting of about 4 or 5 acres. The first planting of avocados has made an excellent growth and should come into bearing in about two years hence. The orchard has been increased in area. A planting of mangoes, consisting of several hundred trees, some of which are inarched and others of which are to be budded, adjoins the orchard of avocados. The other newer plantings in orchard form consist of the following: Oranges (Pl. III, fig. 1), pomelos, lemons, papaias, sweet sop (*Anona squamosa*), sour sop (*A. muricata*), cherimoya (*A. cherimolia*), Kafir plum (*Harpephyllum caffrum*), *Spondius lutea*, guava (*Psidium guajava*), in several varieties, and the star apple (*Chrysophyllum cainito*). About 1 acre has been planted to mulberries, for experiments in the production of food for silkworms, in cooperation with the entomologist.

THE STAR APPLE.

The star apple (*Chrysophyllum cainito*) (Pl. III, fig. 2) is a fruit worthy of much wider cultivation than it receives. There are, in fact, comparatively few specimens of this tree in Hawaii, but sufficient have been grown to show its possibilities. It makes a strong growth, attaining a height of about 25 feet, and is one of the most beautiful fruit trees of small size, the under surface of the leaves being of a rich golden hue. The fruit is about the size of an apple, and when cut in cross sections shows the carpels so arranged as to simulate a star, thus giving the common name to the species. The fruit is globular in form and smooth, varying in color from green to purple. The pulp is of delicious flavor and pleasing texture and should place this fruit with the mangosteen in quality. All the varieties grown in Hawaii are seedlings, but it is highly probable that the tree could be propagated by budding or grafting, and thus perpetuate individual characters of the best varieties.

A few specimens of the star apple have already been planted in the station orchards and are prospering. About 150 seedlings are in the propagating houses and will be set in the orchard and distributed to local growers.

THE ANONA GROUP.

Several species of Anona are found in the gardens of a few cultivators in Hawaii, and at least one species, the cherimoya (*Anona cherimolia*), is found practically wild in Kona, Hawaii, where it has escaped from cultivation. The finer varieties of cherimoya are among the most highly prized of tropical fruits. These are propagated by grafting. The fruit weighs from 3 to 8 pounds, or even as high as

FIG. 1.—AN UNNAMED HAWAIIAN SEEDLING ORANGE.

FIG. 2.—THE STAR APPLE (CHRYSOPHYLLUM CAINITO).

FIG. 1.—THE SOUR SOP (ANONA MURICATA).

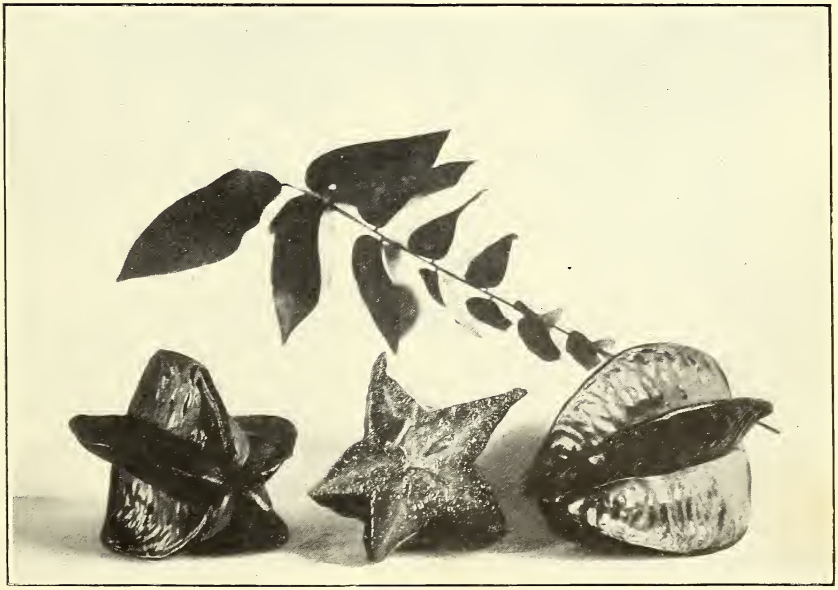


FIG. 2.—THE CARAMBOLA (AVERRHOA CARAMBOLA).

16. Those of ordinary size are reported to sell in the London market at $1.50 each, and the very large ones as high as $2.50 and even $3. This fruit is regularly cultivated in Madeira, and has replaced the grapevine in some parts of the island. From the luxuriant growth which the semiwild plants have made on the slopes of Kona, there is every reason to believe that, with the direct communication between Kona and the mainland which is likely to be inaugurated in the not distant future, the finer varieties of this fruit could be made highly profitable in cultivation. In the sheltered spots at some elevations on the island of Oahu this fruit could probably be grown and marketed in San Francisco. It is said to be a fairly good shipper. The station has already secured a few specimens of valuable varieties of cherimoya. The sweet sop (*A. squamosa*) should also be cultivated more extensively than at present, at least for home consumption. It is a very delicious fruit, though somewhat smaller than the cherimoya. The white flesh surrounds the large black seeds, but is easily separable from them. In form the fruit is heart shaped with an exterior divided into many segments. The sour sop (*A. muricata*) (Pl. IV, fig. 1) is perhaps the most vigorous stock of the Anonas in Honolulu. It appears to be better adapted to low elevations than some of the other members of the group. The fruit is not so universally appreciated as the cherimoya or the sweet sop, but is much liked by some, and is more commonly seen in the market in Honolulu than any other Anona. The pulp is eaten raw or may be used in sherbets.

THE CARAMBOLA.

The carambola (*Averrhoa carambola*) is a Chinese fruit of considerable value. The tree is of beautiful foliage and attains a height of about 20 feet. The fruits are produced abundantly and with their unique form and attractive coloring add much to the beauty of the tree. These fruits (Pl. IV, fig. 2) are deep lobed and star shaped in cross section. They contain an abundance of juice, which may be used in the making of a drink similar to lemonade. There is an acid and also a sweet variety. The station has about 150 seedlings of this also, which will be distributed in part and in part planted in the station orchard.

CARICA QUERCIFOLIA.

This species of Carica is said to be much richer in papaine, or "vegetable pepsin," than the papaia. Several trees of this species have been grown on the station trial grounds and have made a vigorous growth and produced their small fruits abundantly. No tests have

been made of the papaine content. The fruits have a slightly acid taste not found in the papaia, offering an interesting field for cross-breeding.

THE ROSELLE.

The cultivation of the roselle (*Hibiscus sabdariffa*) has been continued during the year. In November and December most of the crop was harvested.

This plant was first introduced in Hawaii from Australia, so far as the writer is informed, by Mr. R. A. Jordan. A supply of seeds was secured by the experiment station from Porto Rico in 1904 and the plants have been grown on a field scale for two years. It gives promise of being a very useful plant.

The fruit of this plant consists of a fleshy calyx and a seed pod which are used in the making of jam, jelly, and a cooling drink. The flavor is tart and, if not obscured by the use of an excessive amount of sugar, resembles closely that of cranberries. In color and general appearance both the jam and the jelly are very attractive. The following directions for the manufacture of jam have been used in experiments conducted by Miss Alice R. Thompson, of this station. The data will also show the quantity of jam or of jelly which can be produced from a given number of pounds of fruit. These experiments were conducted with fruit that was rather overmature and the seed pod was too ripe to be used. When fruits are young the whole of the fruit may be used.

Roselle jam.—Wash 6 pounds of roselles, open and remove the seed pod. The weight of flesh will be about 3 pounds. Add 2 cups of water to the berries and cook about an hour until reduced to a soft pulp. Measure the cooked fruit and add $1\frac{1}{4}$ cups of sugar to each cup of fruit. Cook twenty minutes.

Six pounds of roselles will make 7 pounds of jam or 11 half-pint cupfuls.

Roselle jelly.—Wash and seed 4 pounds of roselles. The weight of the flesh will be about 2 pounds. Add 4 cups of hot water and boil to a pulp. Strain the whole through a cloth bag without pressing. Measure the juice and boil it continuously twenty minutes. Then add 1 cup of sugar for each cup of juice. The sugar should be heated in the oven before adding it to the juice, so that the boiling will not be interrupted. Cook until, on testing the consistency of the liquid by pouring from a spoon, the last drop adheres to the spoon. Remove from the fire and pour into the jars. Four pounds of roselles will make 2 pounds of jelly or 2 half-pint cupfuls.

Cultivation of roselle.—It is best to plant the seeds in boxes or seed beds about the last of February or the first of March in Honolulu and

transplant to the open field when the plants have attained a height of 6 or 8 inches. From the experience of the last two years at the station, there appears to be nothing gained by planting seed earlier than February. Seed planted before this date has produced plants which have borne prematurely and have not produced the main crop earlier than those from seed planted later. The plants should stand about 3 to 4 feet apart in the row and the rows from 4 to 6 feet apart. If the soil is good and moisture abundant, 4 by 6 feet will not be too great a distance.

The soil for the roselle need not, however, be the richest, but good soil will yield correspondingly good results. The harvest comes on about November and December in Honolulu. It is quite possible that in other parts of the islands other seasons for planting may be found preferable and the crop may mature earlier or later.

The after cultivation will consist only in keeping the soil well tilled and supplied with moisture.

The yields in the experiments conducted at the station would average from 6,000 to 7,000 pounds per acre with a very moderate use of water. The cost of picking these fruits would be from ½ to ¾ of a cent a pound. At 4 cents per pound net to the grower, these fruits could be placed on the market at a price very much lower than cranberries. Allowing ¾ of a cent for the cost of gathering and ¼ of a cent for packing materials, there would remain 3 cents per pound as the value of the fruit on the plants. These at 6,000 pounds per acre would represent a value of $180 per acre for the crop in the field.

THE NATAL PINEAPPLE.

Specimen plants of the "Natal pineapple," S. P. I. No. 8634, were received and planted August 9, 1905. These plants have fruited during May and June. The aim of the U. S. Department of Agriculture in introducing this fruit has been to place upon the market a fruit of unusual quality in very small size so that they could be served one at each plate. The fruit is small, of very fine color, aroma, and exquisite flavor. No points of difference, however, could be distinguished between this and the Queen variety. They appear to be the same fruit under two different names. This fruit would not be well adapted to canning, but might be desirable for some of the fresh fruit markets where a small fruit is demanded. The Queen is not commercially planted in Hawaii at present, many plants having been destroyed. The Smooth Cayenne has given better results on the island of Oahu, where the largest pineapple plantations are located. This is no doubt due chiefly to its large size and heavy yields. The Red Spanish has found favor in Kona on the island of Hawaii.

GRAPES.

Quite a large number of varieties of grapevines were introduced during the last year, and were placed in charge of a vineyard company on the island of Maui. Some of these varieties are reported to have done unusually well and give promise of being a more profitable vine than those now common in the islands.

MANILA HEMP.

The Manila hemp plant was introduced into Hawaii many years ago, but so far as known to the writer has never been grown on a commercial scale. Seeds of this species were obtained by the station several years ago from which quite a number of plants were grown. These have made a more vigorous growth than any other species or variety of the genus Musa on the experiment station lands. There are many steep gulches in the islands where the Manila hemp might be grown and, judging from the progress which these trial specimens have made, should prove very profitable as a source of the much-prized rope fiber of commerce.

PLANTINGS ON THE HIGHER ELEVATIONS OF THE STATION LAND.

About 2 or 3 acres, at an elevation of approximately 1,000 feet, have been cleared during the year and planted to peaches, figs, oranges, lemons, pomelos, loquats, mulberries, grapes, and strawberries. A small planting of papaias and of citrus stocks for budding occupies part of this area. The coffee and most of the other plants at this elevation which have been set out in previous years are making satisfactory progress. The avocados on this land, which were planted many years before the station was established, are an interesting field for study in the causes of barrenness and also of lack of quality in the fruit. Some of the trees have refused to bear, while others have produced very indifferent fruits. These characters may be inherent in the trees or may be in part due to uncongenial environment. This elevation may approach the limit for the production of the best fruit. The effect of liberal fertilizing is being tried on some of these trees.

DECIDUOUS PLANTINGS.

The horticulturist superintended the planting of about 6 acres of deciduous orchards on lands belonging to the Parker ranch on the island of Hawaii, at elevations varying from 2,700 to 5,000 feet. These consisted of the following: 125 apples, 100 pears, 100 cherries, 100 apricots, 10 almonds, 10 walnuts, 100 plums, 100 peaches, 10 figs, 5 oranges, and 5 lemons.

A few apple trees, which were planted at about 4,000 feet altitude several years ago, have made a very fine growth and were well supplied with fruit buds at the time when the last plantings were made. This is mentioned here as of considerable interest, being perhaps the largest mixed planting of deciduous fruits that has been made in the islands.

DISTRIBUTION OF SEEDS AND PLANTS.

The distribution of seeds and plants has come to be a very considerable factor in our work. The station can in this way be of direct assistance to many. The aim has been to distribute such species and varieties as are not readily obtainable elsewhere. The miscellaneous distribution of ordinary vegetable and flower seeds has not been encouraged.

The request for varieties of bananas from the station collection has exceeded the supply in all varieties except the Jamaica or Bluefields. There have been requests from many parts of the Tropics for specimens of the Hawaiian bananas and to such a degree that it has been necessary to suspend further distribution during part of the year.

The number of visitors at the station who wish to look through the grounds and propagating houses has increased greatly during the year. Instruction in methods of cultivation has thus been given verbally and by demonstration, including such subjects as budding, grafting, pruning, etc. In some cases it has been necessary for the horticulturist to visit the grounds of the inquirer.

HORTICULTURAL EXHIBIT.

In December, 1906, the station cooperated with the Hawaiian Poultry Association in a public exhibition held in Honolulu. The horticulturist gave considerable time to the collection and arrangement of specimens for this exhibit. Though not a good season for an exhibit of horticultural products, by the cooperation of many interested parties a creditable collection of specimens was brought together. This fair had certainly considerable educational value, and arrangements have been made for another exhibit during the coming season.

The horticultural exhibit on the part of the station consisted chiefly in fruit packages, illustrative of methods of packing used in fruit-shipping experiments of the preceding season. The roselle was also shown in quantity and attracted much attention as a new fruit worthy of cultivation.

THE NEED OF ASSISTANCE.

The work of the propagating houses and the experimental plats and orchards has greatly increased, demanding constant and careful attention. With the other work that has been done it has been impossible to devote as much time to this as it requires. During the past year the horticulturist has been absent from the station on official duty about three months, a considerable portion of which was spent on the mainland of the United States.

The need of an assistant has been recognized for a long time, and only the lack of sufficient financial resources has prevented the securing of aid. It is expected that a man can be secured during the next few months. This should add greatly to the efficiency of the work.

REPORT OF THE ASSISTANT CHEMIST.

By Miss Alice R. Thompson.

During the past year a large number of miscellaneous analyses were made, among them 49 samples of Hawaiian honey, special attention being given to the honeydew honey; 13 samples of fertilizers were analyzed for the fertilizer experiments carried on with rice by Mr. F. G. Krauss; 10 samples of soils of different origin; several salt determinations of waters and soils, and about 40 samples of fodders and feeding stuffs. The analyses of the honey samples are reported in a bulletin of the station.[a] The other analyses, except the fertilizers, are given in the accompanying tables.

ANALYSES OF HAWAIIAN SOILS.

Ten samples of soils were received and analyzed and the analyses are as follows:

Analyses of samples of Hawaiian soils.

Number of sample.	Moisture.	Organic matter and combined water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Manganese oxid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10.980	28.242	1.036	0.191	0.132	1.995	3.376	0.225
2	10.707	25.499	.840	.159	.145	1.880	3.687	.185
3	7.309	16.942	.313	.172	.361	.27	.608	.37
4	6.629	17.914	.238	.264	.515	.275	.535	.105
5	8.435	9.253	.232	.436	.324	1.470	1.575	.070
6	10.466	18.100	.477	.322	.126	1.135	1.838	.075
7	10.568	18.667	.435	.102	.331	.480	.835	.075
8	8.222	17.091	.336	.045	.339	.275	.559	.160
9	8.028	18.907	.273	.146	.283	.130	.711	.105
10	8.786	10.224	.153	.275	.659	.995	3.500	.20

Samples 1 and 2 were taken at Olaa, Hawaii. Both are brown sandy soils and acid in reaction with litmus paper, in spite of the amount of lime present, as shown by analysis. The potash content is low. Soil No. 1 has produced some sugar cane. Soil No. 2 is from coffee land.

Samples 3 and 4 were taken from pineapple land on Kauai. The pineapples growing on the soil were troubled with root disease. Both soils are brown loams and they react acid with litmus. Analysis shows a deficiency of lime in the soils.

[a] Hawaii Sta. Bul. 17.

Sample 5 is soil from the rice fields at the experiment station trial grounds. The soil is a gray loam, is not acid, and contains but a trace of chlorin.

Samples 6 and 7 were taken at Keanae, Maui. Sample 6 is a dark sandy soil, acid in reaction, and containing a trace of salt. Analysis shows a deficiency of potash.

Sample 7 is a brown sandy soil, also acid in reaction. Analysis shows a deficiency of lime.

Samples 8 and 9 are from Hanapepe, Kauai. Pineapples are raised on this soil. Both soils are brown loams and acid. The lime content is low in both. Phosphoric acid is low in No. 8.

Sample 10 was taken at Kaimuku. The soil is a red clay loam.

SALT DETERMINATION IN WATERS AND SOILS.

Mr. J. P. Colburn sent to the station for salt determination three samples of water from wells to be used in irrigating rice fields. Sample No. 1 contained 129.41 grains per gallon, No. 2 contained 74.53 grains, and No. 3 contained 113.83 grains.

To determine the amount of salt tolerated by rice Mr. F. G. Krauss, rice expert, brought two samples of water from rice fields for analysis. Sample No. 1, water in which rice grew well, showed a salt content of 1.69 grains to the gallon. Sample No. 2, from a rice field in which only rice of an inferior quality grows, contained 56.915 grains per gallon. The rice field from which the latter sample was obtained comes in contact with tide water.

From these results it would seem that rice fields irrigated with water containing 74.53 grains per gallon could produce rice of inferior quality. Mr. Colburn's sample No. 1 indicates a water of even higher salt content, which even rice of inferior quality would scarcely tolerate.

Another sample of irrigation water was submitted and on analysis was found to contain 9.316 grains of salt per gallon.

The salt content of four samples of soil was later determined. These samples were selected by Mr. F. G. Krauss from rice fields in which the salt content varied. The samples upon analysis were found to contain 0.00556, 0.00092, 0.00037, and 0.00002 gram of sodium chlorid per gram of sample. The first three samples were taken from Waikiki rice fields and the fourth sample was from the station's trial grounds near Waikiki. In the first soil rice does not grow, in the second it barely survives, while in the third soil it grows well.

COMPOSITION OF HAWAIIAN FEEDING STUFFS.

The analysis of fodders has continued to be part of the routine work to the laboratory. Forty samples have been analyzed, the methods used being those adopted by the Association of Official Agricultural Chemists. Reference may be made to Bulletin No. 13 of this station, which contains the analyses of a number of Hawaiian feeding stuffs, the present report being a continuation of the work as set forth there.

The composition of the fodders analyzed is as follows:

Composition of Hawaiian feeding stuffs.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.									
Sorghum:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	75.11	1.71	1.76	13.56	5.45	2.41	0.31	0.12	0.09
Sample No. 2	78.92	1.38	.34	11.67	5.59	2.10	.27	.10	.09
Sample No. 3	62.79	2.53	.74	22.03	8.54	3.37	.....	.19	.25
Average	72.27	1.87	.94	15.75	6.52	2.62	.29	.13	.14
Sorghum silage	76.76	2.04	.73	12.62	5.68	2.17	.38	.08	.13
Corn cut for silo	76.45	1.64	.24	12.67	6.43	2.57	.33	.08	.12
Corn silage	81.63	2.06	.31	6.61	4.35	5.04	.48	.16	.09
Millet roots (*Sorghum halepense*), air dried	11.18	7.22	.39	27.56	40.82	12.83	2.60	.06	.19
GRASSES.									
Hilo grass (*Paspalum conjugatum*):[a]									
Sample No. 1	70.48	1.52	.40	16.43	9.44	1.73	.40	.19	.06
Sample No. 2	71.70	1.43	.54	15.18	9.39	1.76	.43	.15	.06
Sample No. 3	73.20	1.38	.86	14.02	9.05	1.49	.37	.18	.06
Average	71.79	1.44	.60	15.21	9.29	1.66	.40	.17	.06
Rhodes grass (*Chloris gayana*):[b]									
Sample No. 1	64.78	2.81	.52	16.08	12.52	3.26	.50	.26	.16
Sample No. 2 (air dried)	10.87	9.00	1.53	38.05	27.36	13.19	1.31	.71	.95
Pili grass (*Heteropogon contortus*)[c]	66.93	2.05	.44	15.43	11.79	3.36	.44	.08	.13
Redtop (*Tricholæna rosea*), air dried	8.84	3.38	1.21	45.14	35.48	5.95	.59	.33	.28
Paspalum dilatatum[d]	72.95	1.96	.72	13.38	8.86	2.13	.52	.20	.12
Para grass (*Panicum molle*):[e]									
Sample No. 1	72.18	3.46	1.33	11.04	7.65	4.34	.....	.16	.24
Sample No. 2	72.10	1.43	.29	13.31	11.19	1.68	.08	.09	.12
Side oats grama (*Bouteloua curtipendula*)[f]	39.47	6.43	1.05	27.68	18.12	7.25	.71	.21	.27
English and Italian rye grass (*Lolium perenne* and *L. italicum*)[g]	27.44	6.49	1.43	36.68	20.94	7.02	1.86	.44	.41
Wheat hay (containing a little oats)[h]	11.91	7.96	.94	38.27	30.09	10.83	3.31	.20	1.03
Rice straw[i]	10.89	4.81	2.67	36.91	24.84	19.88	.....	.39	.41

[a] From Parker ranch, No. 1 below Baker's, No. 2 from Waihaka, and No. 3 at Baker's.
[b] No. 1 from Molokai ranch, 800 feet; No. 2 from Parker ranch.
[c] From Molokai ranch, 700 feet.
[d] From Molokai ranch.
[e] No. 1 from Waikiki, Oahu; No. 2 from Olaa.
[f] Grown at the experiment station, Oahu.
[g] From Parker ranch.
[h] From Waimea.
[i] Grown at Waikiki, Oahu.

Composition of Hawaiian feeding stuffs—Continued.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
LEGUMINOUS FORAGE CROPS.									
Alfalfa:[a]	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	76.61	6.78	0.77	8.73	4.24	2.87	0.98	0.39	0.21
Sample No. 2	73.83	5.25	.76	11.21	5.56	3.39	1.00	.35	.23
Sample No. 3	72.18	8.00	.72	9.44	6.27	3.39	.....	.50	.22
Average	74.20	6.67	.75	9.79	5.35	3.21	.99	.41	.22
Cowpea (*Vigna sandwichensis*)[b]	82.35	3.06	.58	7.24	4.22	2.55	.62	.34	.14
ROOTS USED AS FORAGE.									
Cassava refuse from crude extract of starch	15.46	1.21	.10	76.93	5.45	.85	.314	.17	.04
Cassava waste (first washing for starch manufacture)	16.30	1.31	.22	79.82	1.08	1.27	.08	.10	.08
Taro waste	70.73	.36	.24	27.25	.89	4.36	.13	.05	.07
Tacca pinnatifida	66.89	1.93	.12	29.64	.58	.84	.39	.06	.07
Ti root	16.78	3.76	.16	42.28	5.40	1.62	.27	.56	.09
Beet, Yellow Tankard	94.12	1.00	.04	2.62	.97	1.25	.40	.02	.05
Beet, Long Red	93.25	1.13	.06	1.80	2.59	1.17	.32	.02	.05
CONCENTRATED FEEDS.									
Algeroba, or kiawe bean (*Prosopis juliflora*):[c]									
Sample No. 1	13.62	8.13	.67	52.38	21.87	3.33	1.35	.19	.29
Sample No. 2	16.37	8.50	.44	53.77	17.47	3.44	1.22	.23	.36
Sample No. 3	15.17	9.73	.45	47.12	23.71	3.82	1.38	.43	.33
Algeroba meal	9.29	10.25	1.16	47.98	27.85	3.52	1.22	.24	.39
MISCELLANEOUS FORAGE CROPS.									
Spanish needles (*Bidens pilosa*)[d]	82.06	3.45	.33	6.48	5.03	2.65	.94	.26	.14
Pakana (*Melilotus officinalis*)[e]	61.28	5.96	.67	17.59	11.90	2.60	.94	.50	.28
Rape[d]	86.10	2.24	.59	6.60	1.76	2.71	.95	.32	.16
Annual ilima (*Sida* sp.)[d]	77.58	3.93	.39	8.88	5.69	3.53	.81	.80	.32

[a] No. 1 and 2 from experiment station, Oahu; No. 3 grown at Waikiki, Oahu.
[b] From Kamehameha Schools, Oahu.
[c] Sample No. 1 was passed through a sieve having $\frac{3}{16}$-inch meshes, No. 2 through a sieve having $\frac{1}{8}$-inch meshes, and No. 3 was chopped coarse.
[d] From Molokai ranch.
[e] From Parker ranch.

Composition of Hawaiian feeding stuffs.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.							
Sorghum:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	6.89	7.08	54.45	21.90	1.23	0.48	0.35
Sample No. 2	6.53	1.60	55.39	26.52	1.30	.48	.43
Sample No. 3	6.81	2.00	59.18	22.95	.....	.52	.67
Average	6.74	3.56	56.34	23.79	1.26	.49	.48
Sorghum silage	8.78	3.14	54.29	24.45	1.62	.36	.55
Corn cut for silo	6.97	1.01	53.78	27.31	1.40	.34	.05
Corn silage	11.19	1.70	35.96	23.69	2.59	.88	.49
Millet roots (*Sorghum halepense*)	8.13	.41	31.02	45.96	2.93	.07	.21

Composition of Hawaiian feeding stuffs—Continued.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
GRASSES.							
Hilo grass (*Paspalum conjugatum*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	5.14	1.35	55.66	31.99	1.35	0.65	0.22
Sample No. 2	5.04	1.92	53.62	33.18	1.52	.53	.26
Sample No. 3	5.14	3.22	52.31	33.78	1.37	.69	.22
Average	5.10	2.16	53.86	32.98	1.41	.62	.23
Rhodes grass (*Chloris gayana*):							
Sample No. 1	8.01	1.47	45.65	35.62	1.41	.74	.45
Sample No. 2	10.04	1.72	42.78	30.69	1.47	.79	1.06
Average	9.02	1.59	44.21	33.15	1.44	.76	.75
Pili grass (*Heteropogon contortus*)	6.2	1.31	46.70	35.64	1.34	.24	.39
Para grass (*Panicum molle*):							
Sample No. 1	12.44	4.78	39.67	27.51	.....	.56	.87
Sample No. 2	5.13	1.03	47.70	40.11	.29	.34	.42
Redtop (*Tricholæna rosea*)	3.71	1.32	49.53	38.92	.64	.36	.30
Paspalum dilatatum	7.25	2.67	55.97	32.77	1.92	.74	.44
Side oats grama (*Bouteloua curtipendula*)	10.63	1.73	45.72	29.94	1.18	.34	.44
English and Italian rye grass (*Lolium perenne* and *L. italicum*)	8.94	1.97	51 15	28.86	2.57	.61	.57
Wheat hay (containing some oats)	9.04	1.07	43.44	34.16	3.76	.23	1.16
Rice straw (upper half as gathered)	5.38	2.99	41.44	27.88	.....	.44	.46
LEGUMINOUS FORAGE CROPS.							
Alfalfa:							
Sample No. 1	29.00	3.70	36.91	18.12	4.21	1.69	.88
Sample No. 2	20.06	2.91	42.81	21.26	3.83	1.33	.89
Sample No. 3	28.75	2.58	33.94	22.55	.....	1.81	.80
Average	25.93	3.06	37.88	20.64	4.02	1.61	.85
Cowpea (*Vigna sandwichensis*)	17.31	3.29	41.03	23.93	3.52	1.94	.78
ROOTS USED AS FORAGE.							
Cassava refuse from crude extract of starch	1.44	.12	90.99	6.45	.37	.19	.05
Cassava waste (first washing for starch manufacture)	1.57	.26	95.37	1.29	.09	.12	.10
Taro waste	1.24	.83	93.41	3.03	.46	.16	.22
Tacca pinnatifida	5.82	.35	89.55	1.74	1.19	.18	.22
Ti root	7.06	.30	79.45	10.14	.50	1.05	.16
Beet, Yellow Tankard	17.06	.74	44.41	16.51	6.78	.28	.90
Beet, Long Red	16.87	.85	26.62	38.36	4.80	.24	.79
CONCENTRATED FEEDS.							
Algeroba, or kiawe bean (*Prosopis juliflora*):							
Sample No. 1	9.38	.77	60.69	25.31	1.56	.22	.33
Sample No. 2	10.14	.53	64.33	20.88	1.45	.28	.43
Sample No. 3	11.44	.53	55.56	27.95	1.62	.51	.39
Algeroba meal	11.26	1.27	52.90	30.70	1.34	.26	.43
MISCELLANEOUS FORAGE CROPS.							
Spanish needles (*Bidens pilosa*)	19.28	1.82	35.99	28.11	5.27	1.46	.81
Pakana (*Melilotus officinalis*)	15.39	1.74	45.43	30.73	2.44	1.30	.72
Rape	16.10	4.24	47.46	12.69	6.86	2.30	1.51
Annual ilima (*Sida* sp.)	17.55	1.76	39.55	25.37	3.62	3.60	1.46

Nitrogenous constituents of Hawaiian feeding stuffs.

[Fresh material.]

Kind of feeding stuff.	Total nitrogen.	Proteid nitrogen.	Amid. nitrogen.	Crude protein (total N×6.25).	True protein (protein N×6.25).	Amids calculated as asparagin.
NONSACCHARINE AND SACCHARINE FORAGE.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sorghum: Sample No. 1	0.274	0.244	0.030	1.71	1.53	0.14
Corn	.260	.181	.079	1.63	1.13	.37
GRASSES.						
Rhodes grass (*Chloris gayana*): Sample No. 1	.451	.278	.173	2.82	1.74	.81
Water grass (*Paspalum dilatatum*)	.314	.054	.260	1.96	.34	1.22
Pili grass (*Heteropogon contortus*)	.328	.245	.083	2.05	1.53	.29
LEGUMINOUS FORAGE CROPS.						
Cowpea (*Vigna sandwichensis*)	.489	.369	.120	3.06	2.31	.56
ROOTS USED AS FORAGE.						
Beet, Yellow Tankard	.161	.072	.089	1.01	.45	.42
Beet, Long Red	.182	.095	.087	1.14	.59	.41
CONCENTRATED FEEDS.						
Algeroba or kiawe bean (*Prosopis juliflora*):						
Sample No. 1	1.295	.781	.514	8.09	4.88	2.42
Sample No. 2	1.358	1.141	.217	8.49	7.13	1.02
MISCELLANEOUS FORAGE CROPS.						
Spanish needles (*Bidens pilosa*)	.552	.095	.457	3.45	5.94	2.15
Rape	.358	.289	.069	2.24	1.81	.32
Annual ilima (*Sida* sp.)	.629	.428	.201	3.93	2.68	.94

RICE INVESTIGATIONS—REPORT OF FIRST YEAR'S EXPERIMENTS.

By F. G. Krauss.

INTRODUCTION.

Rice, while second to sugar as an agricultural product and far below it in magnitude and value, is still the most extensively consumed in Hawaii of any product of the land. If every other crop should fail and supplies from the mainland be cut off, the subsistence of its inhabitants would be assured by this one staple crop.

The growing of rice occupies 10,000 or more acres, and as practiced in Hawaii it is an intensive rather than an extensive culture, 100 acres constituting a large plantation. The rentals of rice lands are high, ranging from $10 to $50 per acre per annum with water privileges. This necessitates careful and continuous culture to produce maximum crops, although the annual acre yields in Hawaii compare favorably with the best in the world. Two crops a year are usually grown on the same land, thus occupying the ground continuously, especially when slow-maturing varieties are grown. The usual practice is to propagate the seedlings in seed beds, from which the entire crop is transplanted by hand.

Tillage methods, while antiquated, are thorough, as is also the practice of irrigation and drainage. To a limited extent the application of fertilizers is followed. The sickle is used in reaping, thrashing for the most part is done by the treading of horses, and the grain is winnowed by hand.

The average annual yield (two crops) on good lands in favorable localities is 6,000 pounds of paddy per acre, while 8,000 pounds or more is not uncommon. At present prices,[a] which are exceptionally good, an acre will produce a crop valued at from $100 to $200. The estimated annual value of the Hawaiian rice crop in a favorable year is approximately $2,500,000.

In this report little more than a record of a first series of experiments is attempted. The data presented, however, were obtained under favorable conditions and should prove reliable on this account.

[a] The price of paddy (unhulled rice) is about half of that of the milled marketable table rice, and during the spring of 1907 ranged from $2.20 to $2.70 per 100 pounds.

The writer desires to acknowledge the valuable assistance and cooperation of Messrs. Ching Shai, Wong Leong, and Ching K. Ai, prominent Hawaiian rice growers; Dr. N. A. Cobb, in the work on the diseases affecting Hawaiian rices and upon the sedges entering into these experiments; Mr. D. L. Van Dine, entomologist of the station, in determining insect pests affecting rice; and Miss Alice Thompson, assistant chemist, in preparing the chemical data affecting these experiments and in making numerous calculations. To Director Jared G. Smith's valuable suggestions and constant encouragement the main credit of much of this work is due.

PLANS, OBJECTS, AND METHODS OF THE EXPERIMENTS.

The past year has been devoted to a study of the fertilizer requirements of the rice plant and of rice soils, and to the development of superior varieties and strains of rice through the improvement of some of the best of the old varieties and by selection from the best foreign varieties. In connection with the experiments an exceptional opportunity was offered for determining a number of other factors in the production of rice. Among these are the influence of the age of seedlings at the time of transplanting; tillering of the rice plant as affected by the number of seedlings set in a clump at transplanting; relative yields from broadcasted, drilled, and transplanted rice; and the duty and influence of irrigation water.

In pursuing these investigations field trials were made of rice machinery. These took up comparatively little time, but sufficient was done to interest implement manufacturers, who will probably make more exhaustive tests than are possible by the station.

The station was fortunate in securing a conveniently located tract of land for experimental purposes. This land had been under rice culture for a number of years, excepting a small portion, which was planted to bananas at the time it was turned over to the station, in August, 1906. That portion which had been devoted to rice growing had received no fertilizer for a number of years, yet it had invariably yielded crops approximating 3,000 pounds of paddy per acre per harvest. However, owing to the porous nature of the soil, which necessitated an excess of irrigation, other crops were being gradually substituted for rice.

A chemical analysis of the soil was made at the time the station took possession of the land in 1906, and its principal constituents are shown in the following table:

Partial chemical analysis of the soil of the rice trial grounds.

	Per cent.
Moisture	8.435
Organic matter combined with water	9.253
Lime (CaO)	1.470
Magnesia (MgO)	1.575
Phosphoric acid (P_2O_5)	.436
Potash (K_2O)	.324
Nitrogen total	.232

This analysis shows the soil to be of fair fertility, although low in organic matter. Fully 25 per cent of this soil is coarse gravel and stone, an equal amount is fine gravel and coarse sand, and the remainder fine sand and silt with sufficient clay to permit of puddling the land to hold water enough for the crop.

An artesian well supplied ample pure water for irrigation purposes and avoided contamination in fertilizer experiments.

NOTES ON VARIETY TESTS AND IMPROVEMENT EXPERIMENTS.

In taking up the rice work the station secured as many varieties as possible, and early in 1906 succeeded in obtaining through the Office of Experiment Stations and the Bureau of Plant Industry of the U. S. Department of Agriculture about 150 more or less distinct varieties of rice. The descriptions and other data accompanying many of these varieties were meager but were carefully recorded, in order that the original descriptions could be compared with specimens grown from the different samples. A 10-gram sample of each variety was reserved for future reference, and these have already proved invaluable in the study of varieties in the two succeeding generations.

So far as the physical characteristics of the unhulled seed are concerned, comparisons that have thus far been made show but slight variation from the original specimens, except in color, the hulls invariably changing to a darker color with age, probably under the influence of light. It is possible that changes in environment may alter the chemical composition of the grain, and investigations in this direction are now under way.

Germination tests were made of all samples in the laboratory. One hundred and thirty-one varieties germinated, although some showed very weak vitality, due probably to the age of the seed, immaturity at harvest, or insect injury.[a] In several cases the bulk of the seed packet consisted of empty sterile glumes. The few seeds germinating from one of these lots produced perfect plants with a full crop of well-matured seed, while in another instance every flowering glume of the entire plant proved sterile. This would probably indicate a

[a] Several lots of seed, among them S. P. I. Inv. No. 12547, were found to be badly infested with the weevil (*Rhizopertha pusilla*).

tendency toward sterility on the part of that particular variety, since the weather conditions were perfect at flowering time and the adjacent varieties fruited abundantly.

Some stress is laid upon this point, as it frequently happens that in large fields numerous sterile or partially sterile plants are to be found which collectively would considerably reduce the yield. In the improvement of varieties any tendency toward a reduced yield is to be avoided. Whether the tendency to sterility can be transmitted remains to be determined.

In the improvement of varieties by selection as well as in testing varieties in cultural trials, it is of the utmost importance to know definitely their methods of pollination. In the case of the rice plant it has been generally supposed that cross-fertilization is the rule and self-fertilization the exception. Apparently the whole flowering process is favorable to cross-fertilization. The successive stages in the flowering are readily traced from the time in which the glumes open until they close together, enveloping the recently exposed stigma, and now containing the fertilized ovule which is to become the matured seed. The whole process of fertilization in rice is similar to that in wheat described by Hays,[a] except that the rice floret bears six anthers and opens generally between 9 and 10 o'clock in the morning and frequently does not close until noon. The flowering period of an individual floret is usually completed within an hour.

Based upon careful observation and experiment, the writer believes that self-fertilization is the rule in rice as it apparently is in wheat. Since these rice experiments were inaugurated more than 100 varieties have been grown in close proximity for from two to four generations without a single cross-bred plant having been found. To test the belief in self-fertilization numerous individual plants of several varieties were protected from foreign pollen by double fine gauze bags before the flowering stage, and all fertilized perfectly except those experimented with during periods of heavy rain.

In the original more than 100 varieties of rice received at the station from many sources there appeared considerable mixtures, which were at first believed to be due to deterioration or possibly to results of accidental crossing. To determine this point a variety grown experimentally at the Georgetown Botanical Gardens from imported Ceylon stock was selected as being the most impure of any. From this six or seven distinct types were separated and grown separately. All but one reproduced themselves closely as to type, so far as the physical appearance of the paddy was concerned. The second generation is now maturing, and, so far as harvested, each of the selections seems to maintain its original physical type.

[a] U. S. Dept. Agr., Div. Veg. Physiol. and Pathol. Bul. 29.

FIG. 1.—GENERAL VIEW OF RICE PLATS.

FIG. 2.—UPLAND RICE GROWN UNDER MINIMUM AMOUNT OF WATER.

A number of theories have been advanced to explain the cross-fertilization of cereals, but the author believes that the stigma does not become receptive until at the very moment the anthers shed their pollen. The pollen is then immediately received on the stigma and fecundation takes place. This seems to be borne out by the great rapidity with which the ovules develop. If this theory is true, the subsequent contact of foreign pollen is without influence. If, however, for some reason the stigma fails to receive pollen from the anthers in the same floret, then a deposit of foreign pollen may fertilize, even after a considerable interval of time. So far as the experiments have been carried on, however, there seems to have been no indication of crossing in the field.

METHODS OF CULTIVATION.

In the trial grounds near Honolulu an acre was divided into plats (Pl. V, fig. 1), and half of the tract was diked for permanent flooding and the remainder left for dry-land culture (Pl. V, fig. 2). It was planned to test each variety in both cultures to determine their drought-resisting and water-tolerance properties. After thoroughly tilling the land in a dry state with disk implements to a depth of 6 inches the first water was turned on August 20, previous to sowing the seed. In Hawaiian rice culture much of the tillage is done while the field is submerged. This is done partly to puddle the ground, thus economizing the irrigation water. The soil of these experimental plats being of a porous nature, as has already been mentioned, prevented any accumulation of surface water, and this necessitated the thorough puddling of the land, which was done with horses and a spike-tooth harrow. After this had been accomplished the 2-inch stream available supplied all the irrigation water needed.

After irrigating the tract the water was allowed to recede, and on account of the gravelly nature of the soil the drilling of the seed was commenced within forty-eight hours. To give all varieties an even start the entire list was sown August 25, flooded and immediately drained again, and so left until all the varieties had made several inches' growth.

Marked differences were noted in the germination of the varieties, the differences being due, it is believed, to the age of the seed, their moisture content, and the imperviousness of the hulls. The first varieties appeared above ground in fifty-eight hours and the last in one hundred and twenty-five hours, but no subsequent sowings from home-grown stocks have shown anything like as wide a range in germination. When the plants had attained a height of about 6 inches, they were thinned so as to stand about 6 inches apart. Equal numbers of the strongest, weakest, and intermediate plants were permitted to remain for the sake of obtaining as great diversity as pos-

sible. After the thinning was completed the land was permanently flooded.

Field notes were made throughout the season and comparisons made between the different varieties and several standard Hawaiian varieties under identical conditions. Records were kept of the amount of seed sown, tillering, date of flowering, date of maturity, germination, vigor. date of harvest, height and spread of plant, inclination to lodge, shattering of seed, freedom from disease, total yield and variation in yield of individual plants, quality, etc.

BREEDING EXPERIMENTS.

As each variety matured it was carefully inspected and all sports and rogues staked and recorded. The variety was then examined a second time and the best 20 plants pulled up by their roots. These were taken to the laboratory, and the fruit-bearing culms carefully compared until all but five plants were eliminated. The seeds of these were removed and weighed to determine the relative yields. Other things being equal, the two most prolific were reserved as seed for mother plants from which to develop a pedigreed stock. Wherever possible 100 plants of the unselected stock, including the 18 rejected plants from the first selection, were carefully thrashed, weighed, and the approximate acre yields calculated. In this calculation 100 plants were taken as representing a factor in estimating acre yields. In Hawaiian rice culture approximately 50,000 clumps, consisting of 4 or 6 plants each, are set per acre.

It should be stated that in Hawaiian culture all rice is transplanted, while in most of the experiments here described the seed was drilled directly into permanent rows, so that the yields as recorded from the comparative variety tests are only approximations of what they might be under the usual cultural methods.

Of the one hundred and more varieties under test, 11 have thus far been selected as being suitable for Hawaiian conditions. A number of these are upland rices, which produce a fair yield with a minimum supply of moisture. They are all hardy, having been brought from northern China, are early maturing, and produce an excellent hay for horses and cattle. Though all are of the bearded type, no ill effects have been observed to result from their feeding. There is every reason to believe that the culture of upland or dry-land rice will become an important factor in Hawaii's agriculture.

Among the varieties were some promising wet-land rices of the short, thick-kernel type characteristic of Japan rice, the demand for which is yearly growing, on account of the large population of Japanese in Hawaii. One of these varieties was introduced into Hawaii in 1903 or 1904 by Mr. Wong Leong, an extensive rice grower at Kailua, Oahu. Mr. Wong Leong imported four varieties of rice

from Yokohama, Japan, only one of which proved suitable for Hawaiian conditions. Of this he now grows 50 to 80 acres annually and is constantly increasing the area. Comparatively little of this variety is grown elsewhere in Hawaii, but its culture is sure to extend as the demand for it increases.[a]

A pound sample of this variety was secured early in 1906 and sown in drills, the thinned-out plants being transplanted later. Much irregularity was noted as the plants matured. A small percentage showed a short-bearded form. Some tillered freely, while others produced only two or three fruiting culms. However, the seed set well, and its early maturity, compared with the slow-maturing Hawaiian varieties of the Gold Seed type, made a favorable impression from the first.

It was noticed in testing this variety that the transplanted seedlings tillered more freely and developed better panicles than the direct-sown seed; and, furthermore, that the earlier transplanted seedlings yielded almost twice as much seed as older seedlings transplanted later (see p. 88). This gives a valuable clue to a general complaint that the Japanese rices are small yielders when compared with the standard Hawaiian sorts. Careful selections were made of the best individual plants, and these form the basis of a choice pedigree strain which is about to be distributed by the station. This variety has been given a station inventory number, and it is frequently referred to in this report as No. 153.

A second variety, No. 144 (S. P. I. Inv. No. 12765), was received through the Office of Experiment Stations of the U. S. Department of Agriculture as coming from Japan and was labeled Ko-Zo.[b] The few seeds available were sown in August, 1906, but only a single plant was brought to maturity. The seed from this was preserved and carefully propagated. This variety tillers much more freely than No. 153, and the plants yield twice, and in some cases three times, as much paddy, although the grain is somewhat smaller in size. The quality of this rice is considered excellent, and the stock of it will be multiplied as rapidly as possible.

A variety known as No. 65 (S. P. I. Inv. 17144) is an Egyptian variety, extensively grown in Louisiana where, according to Dr. S. A. Knapp, it is locally known as "Bull Rice."[c] No variety in all the

[a] The Japanese residents in Hawaii prefer the rice imported from their own country, paying $1 more per 100 pounds for it.

[b] Possibly intended as Kiushu, a district in Japan where some of the best types of Japan rice are grown.

[c] Accompanying this variety were the following notes: "The Egyptian rice is locally known in Louisiana as 'Bull Rice' and has been grown there for many years. It has a berry of the Japanese type—that is, thick and short kernel, somewhat larger than the Kiushu rice, dark colored and much softer when it first ripens, so that it answers excellently for the purpose of stock feed.

trials has made as good a showing from the very beginning and maintained its lead so well as this. Its general uniformity, good yielding qualities under wet and dry cultural methods, erect, vigorous growth, apparently small waste in milling, and its adaptability for all-season cropping commend it strongly as a general-purpose variety. Its culinary qualities are yet to be determined.

A comparative study was made between plats of standard Hawaiian Gold Seed, Japan Seed rice, and the Egyptian variety just mentioned. These three varieties were grown under like conditions and represent results obtainable under the best methods of culture.

Comparison of standard Hawaiian Gold Seed, Japan Seed, and Egyptian varieties of rice.

Name of variety.	Station inventory number.	Date of sowing, 1907.	Date of maturity and harvest, 1907.	Growing period.	Height of plants.	Weight of paddy.[a]	Weight of straw.[a]	Estimated[b] acre yields, paddy.
				Days.	*Inches.*	*Grams.*	*Grams.*	*Pounds.*
Standard Hawaiian Gold Seed	148	Feb. 18	July 20	152	42	32	68	3,730
Hawaiian-grown Japan Seed	153	---do----	June 8	110	36	20	54	3,412
Hawaiian-grown Egyptian	65	---do----	July 20	152	48	43	114	4,129

[a] One clump consisted of three plants set 12 by 12 inches apart, except No. 153, which stood 9 by 9 inches apart.

[b] Based on 43,560 clumps to an acre for varieties Nos. 148 and 65, and 77,440 clumps to an acre for No. 153.

The comparison in this case is believed to be a fair approximation of these varieties. The estimates are based on test cuttings of 100 square feet, the range of error for which has been found to be within 150 pounds of the yield per acre.

Variety No. 152, which was received by the station from Mr. W. S. Lyon, horticulturist in the Bureau of Agriculture, Philippine Islands, under the name Ay-Yujip, from the Igorrote country, where it is classed as the very best rice grown, promises to become a valuable variety, especially for windy locations. In an extensive trial conducted with it during the fall and winter of 1906–7 the severe storms failed to lodge a single plant, and the grain set perfectly, yielding a large crop. The panicles are long and drooping, averaging 10 to 12 inches in length, and are well furnished with seed, though not so compactly as in variety No. 65. The grain is of a characteristic Japanese type, but owing to the short bearded or awned form of the paddy, it would probably not mill so economically as the beard-

It also has more protein than the ordinary rice. The characteristics of its growth are that it requires very little water, has a strong stalk, abundant leaf, is a heavy producer, and will generally make a crop even though the other rices fail. For these reasons it is grown as a stock feed. The seed of the particular rice sent in was obtained about five years ago [through a seed dealer of New Orleans]. It was the only seed which I could purchase which was free from red rice."—KNAPP.

less varieties. A considerable variation prevails in the extent of this awned form, and it is hoped that by selection it will be possible to establish an entirely beardless type. Considerable improvement is already noted in this direction.

Variety No. 42 (S. P. I. Inv. 12867) proved another promising variety, bearing very compact panicles of upright growth, which permits of close planting as an offset to its rather light tillering. This variety was sent to the station under the name Thosar Bhadai ghaiya, from Bengal Province, India.

In the search for a better variety than the Hawaiian Gold Seed, which is the variety grown most extensively in Hawaii, variety No. 39 (S. P. I. Inv. 12852) proved superior in many respects to our best Hawaiian varieties, which it closely resembles in general appearance. The selection made by the station has unusually compact panicles, the spikelets being attached to the peduncles at close intervals, set on short pedicels, which cause the spikelets to lie close together, often overlapping for two-thirds their length. In the Hawaiian strains of Gold Seed the panicles are rather loose and straggling, due to the longer internodes, so that a comparison between the panicles of the two strains shows 10 to 20 per cent more seed in favor of the new variety, due to this cause alone, since the panicles are of about equal size.

This close setting of the seed to produce compact panicles is an important character to be considered in developing the yielding power of rice through selection. It was so noticeable in the early experiments that its application has been practiced almost from the beginning. Attention has been called to this character by Dr. T. Nakamura, of Tokyo, and it has also been pointed out by Mr. Wong Leong, who called attention to its importance.

SUMMARY.

In the improvement of varieties of rice, it is found important to collect and compare as many varieties as possible. Superior varieties may already exist, and by their cultivation time and expense of creating new sorts would be saved. In work of this character selection should never cease, even among the best varieties.

In testing varieties by cultural trials, a single season's test is not sufficient for comparison. In rice, especially where two crops are grown annually, it is of importance to grow all varieties, testing them as spring and fall crops. The experiments have demonstrated that some varieties which yield well from July planting fail if sown in the early spring, or continue to vegetate until late fall, when they flower and fruit at about the same time as summer plantings. As an example of this No. 19 (S. P. I. Inv. 12508), sown August 25, 1906, yielded a splendid crop when harvested December 17, 1906.

On March 7, 1907, a large plat was sown to the same variety, and while the plants had reached the height of 5 to 6 feet on October 20 only an occasional plant was coming into flower. This indicates periods for maturity of 118 days for fall planting and 200 days for spring-planted crops.

All things considered, the all-season varieties are best for Hawaiian conditions, although exceptional qualities in fall varieties may sometimes be used to advantage in a cultural scheme. It may be laid down as a principle that spring varieties also produce fall crops, while fall varieties are not at all suited to spring culture. Fall varieties are usually slow maturing and heavy yielders; they tiller well, and have thick, stiff stems, being resistant to the effect of storms.

The commercial value of the several varieties which the station is about to introduce to the rice growers of Hawaii remains to be proved, and this can be done only in their hands under the varying and less ideal conditions of plantation management.

FERTILIZER AND CULTURE EXPERIMENTS.

INTRODUCTION.

The Hawaiian rice lands have long been noted for their fertility. Under the intensive cultural methods practiced by the Chinese they have yielded crops of extraordinary quantity and fine quality, and in consequence the industry has flourished. However, decreasing yields and deterioration in the quality of the grain are beginning to cause a general awakening. The causes of the smaller and poorer yields are the continuous cropping of lands with this one staple and the lack of a rational system of fertilization to compensate for the heavy drain imposed by the harvesting of two crops annually.

Ordinarily a rotation of crops would suggest itself as a feasible remedy, but the fact that rice is grown on submerged lands restricts its culture to very narrow limits. As a means for the restoration of worn-out rice lands resting the land has been advocated, but the high rentals prevailing practically prohibit the application of this remedy. Some advance has been made in this direction in that paddy fields are being more thoroughly drained at harvest, and the field is permitted to remain in stubble for as long a period as practicable. The fields are then plowed in a half-dry state and left exposed to the air and sun. After varying periods the land is flooded and the resulting mud mass very thoroughly mixed with the Chinese harrow (Pl. VI, fig. 1). This implement is a single-rowed, twelve-toothed contrivance of steel, resembling an immense comb, to which a water buffalo is attached where the land is very soft or a horse where there is good bottom.

FIG. 1.—CHINESE HARROW.

FIG. 2.—TRANSPLANTING RICE SEEDLINGS.

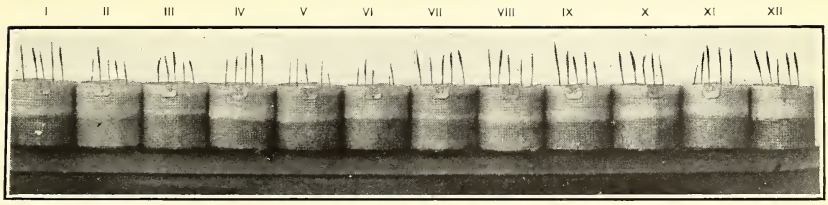


FIG. 1.—STAGE WHEN FIRST WEIGHED, AUGUST 15, 1906.

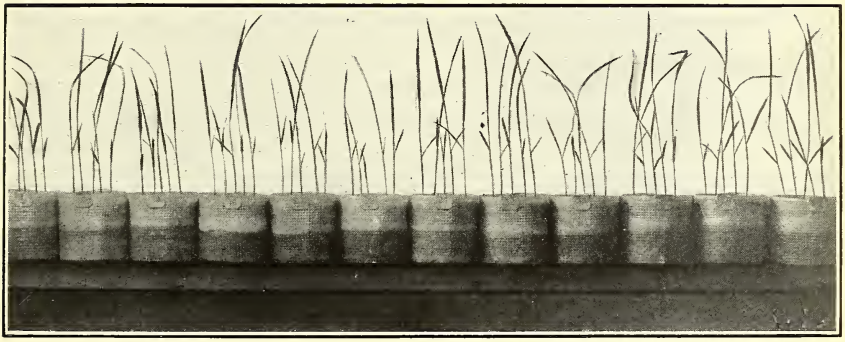


FIG. 2.—INTERMEDIATE STAGE, AUGUST 24, 1906.

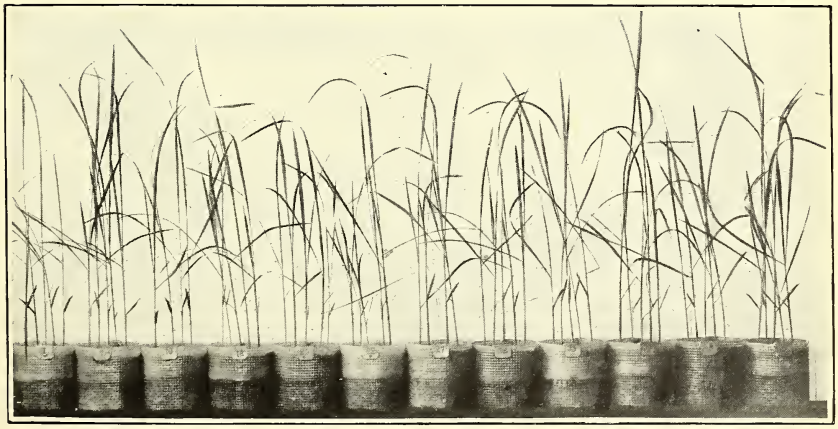


FIG. 3.—CONDITION AT FINAL WEIGHING, SEPTEMBER 24, 1906.

POT EXPERIMENTS WITH RICE, SHOWING EFFECT OF FERTILIZERS.

After this preparation the soil is in condition to receive the crop, and it should be borne in mind that all rice in Hawaiian culture is transplanted (Pl. VI, fig. 2). While such tillage prepares a suitable seed bed, the more important object of cultivation while the field is flooded is to puddle the soil so as to make it more retentive of water. The value of this treatment will be better appreciated when it is known that puddled soils retain their surface flooding from ten to fifty times better than unpuddled fields.

FERTILIZER EXPERIMENTS.

The possibility of economically increasing the yield of the rice crop by the application of commercial fertilizers has doubtless been apparent to many. One would think that in Hawaii, with its splendid object lesson of the results of fertilization of the cane crop, the analogy would readily have suggested itself with other crops. Beyond the application of natural manures, such as have been used for centuries in oriental countries, comparatively little seems to be known of modern methods in plant feeding in relation to the rice crop.

With a view to discovering if possible some of the fertilizer requirements of rice, a series of experiments was planned to determine the influence of chemical fertilizers and natural manures upon the growth and composition of the rice plant under Hawaiian conditions. Two series of soil tests were made by laboratory pot-culture methods, a duplicate series of field plat experiments, and two series of experiments on a field scale. The period covered by these experiments was about fifteen months, beginning July 1, 1906.

The first experiment undertaken was the determination of the manurial requirements of the soil of the rice trial grounds (Pl. VII). For this purpose the paraffined wire-pot method devised by the Bureau of Soils of the U. S. Department of Agriculture was used.[a] This method possesses several advantages over the more cumbersome pots ordinarily used in such cultures, foremost among the advantages being the facility with which transpiration as a determination of growth may be measured, the more normal development of the root system, and the economy of space.

A disadvantage was found in a submerged culture, such as rice, in the danger of leakage liable from the puncture of the frail paraffin covering of the pots. The experiment, however, proved the adaptability of the method, and it was found that the measure of growth as determined by the amount of water transpired by the plants approximated closely the relative weights of the plant in the green and moisture-free conditions.

[a] U. S. Dept. Agr., Bur. Soils Circs. 15, 18; Rhode Island Sta. Buls. 109, 120; Ohio Sta. Bul. 168.

The pots being very small, only 3 inches in diameter and 3 inches deep, the plants could not be grown to maturity, so a period of about thirty days' growth was fixed as the limit, and five rice seedlings were placed in a pot. It has been pointed out,[a] and is also the common observation, that decided soil deficiencies are indicated by the crop long before it has reached its maturity. In so far as a crude but rapid determination of the immediate manurial requirements of the soil is useful as a guidance for further experiment, the wire-pot method commends itself to workers along these lines.

EXPERIMENT I.

This experiment was carried out on lines set forth in Circular 18 of the Bureau of Soils, except that the optimum moisture condition of the soil was made complete saturation, or slightly in excess. This was necessary to supply as normal a condition as possible for rice culture. The soil of the trial grounds was selected for this and most of the subsequent experiments, not because it was typical of the large area of rice lands in the islands, but because it lent itself to a great range of artificial modifications.

A composite sample of the soil was taken, thoroughly mixed and pulverized, after which various fertilizers were added, the amounts used approximating those employed in ordinary field practice. The fertilizers added were dry manure at the rate of 5 tons per acre; lime, 1 ton; nitrate of soda, 200 pounds; sulphate of potash, 200 pounds; acid phosphate, 200 pounds; nitrate of soda and sulphate of potash, 200 pounds each; nitrate of soda and acid phosphate, 200 pounds each; sulphate of potash and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each, to which was added lime, 2,000 pounds; and nitrate of soda, 200 pounds, applied in ten doses at three days' interval. After mixing the fertilizer with the soil it was allowed to stand for several days, when the baskets were filled and the pots arranged in twelve series, each series containing four pots.

Carefully selected one-week-old seedlings of the Hawaiian Gold Seed were used in this experiment, and after they had attained a height of about 1 inch, five seedlings were transplanted to each pot and permitted to attain a growth of 2 inches. The optimum moisture condition having been provided, the pots were sealed over, weighed, and photographed on August 15. From this date they were weighed at three-day intervals until the termination of the experiment, which in most cases was thirty days.

[a] Rhode Island Sta. Bul. 109.

A summary of the results obtained is given in the accompanying table:

Summary of pot experiments with rice, showing effect of fertilizers on growth.

Series No.	Fertilizer used and calculated rate per acre.	Water transpired by 5 plants in total period of growth.	Green weight of 5 plants at end of 30-day period.	Water-free weight of 5 plants at end of 30-day period.	Water transpired per pound of water-free substance.
		Grams.	*Grams.*	*Gram.*	*Pounds.*
1	Check (no fertilizer)	202.0	1.92	0.42	480.95
2	Stable manure—5 tons	287.4	2.75	.60	479.00
3	Lime, air-slaked—1 ton	296.3	2.75	.57	519.82
4	Nitrate of soda—200 lbs.	276.1	2.57	.57	484.38
5	Sulphate of potash—200 lbs.	298.1	2.75	.57	522.98
6	Acid phosphate—200 lbs.	276.7	2.57	.57	485.44
7	Nitrate of soda and sulphate of potash—200 lbs. each	299.7	2.47	.60	499.50
8	Nitrate of soda and acid phosphate, 200 lbs. each	292.9	2.67	.57	513.86
9	Sulphate of potash and acid phosphate—200 lbs. each	235.1	2.37	.50	450.50
10	Nitrate of soda, sulphate of potash, and acid phosphate—200 lbs. each	314.6	2.67	.60	524.33
11	Nitrate of soda, sulphate of potash, and acid phosphate, 200 lbs. each, and lime, 2,000 lbs.	273.3	2.50	.55	496.91
12	Nitrate of soda, applied in 10 doses, 3 days apart—200 lbs.	420.2	4.40	.95	442.10

In the above table the first column gives the amount of water transpired, the second the green weight of the five plants at the end of the experiment, the third the dry weight of the plants, and the fourth the amount of water transpired for each pound of water-free substance produced. This last column, which is the result of computing the other data, shows that the rice plant during the first thirty days of its growth transpires approximately 500 pounds of water to every pound of dry material produced. The smallest proportionate transpiration occurred in the series receiving nitrate of soda at intervals during the experiment, and this series also produced the greatest growth. The next lowest transpiration was found in the series receiving sulphate of potash and acid phosphate.

The most striking result obtained in this experiment was the superior growth obtained where the nitrate of soda was supplied in ten equal doses. The results obtained in this series if compared with the series in which the same amount of nitrate of soda was applied all at one time show marked contrast. The second important result of this experiment is shown in the series where a ton of lime was added to the complete fertilizer. This apparently depreciated the yield below the unlimed series fully 10 per cent. These results are not confirmed in the series which received lime only, but subsequent field experiments strongly emphasized the fact that lime had a depressing effect upon the crop, in the yield of both grain and straw.

The other treatments appeared to exercise a beneficial influence upon the growth of the seedlings, but the results are such as not to

permit of definite conclusions. The least beneficial results were obtained where a combination of potash and acid phosphate was used. In subsequent experiments these two substances gave maximum yields from much smaller applications.

EXPERIMENT II.

The object of this experiment was to determine, so far as possible, by means of pot cultures, the influence upon the yield of grain and straw of the various elements found in commercial fertilizers, used in combination with and without lime. It was planned to grow the plants to maturity, hence larger pots were necessary than those afforded by the paraffined wire-pot method, and glass jars holding 2½ kilograms of dry soil were substituted. Three jars constituted a series. One received an application of lime in addition to the regular fertilizer, the other two remained unlimed. One of these was devoted to a lysimeter experiment, the results of which were too inconclusive for publication. A duplicate of this experiment is under way.

To each pot six selected seedlings of Japan variety No. 153 were transplanted. The soil used was that from the trial grounds, the same as in Experiment I, except that a crop of rice had been harvested since the first experiment. All the fertilizers were mixed with the soil before planting and were contained within the first 3 inches of the soil. The fertilizers were applied at the rate of 50 pounds per acre for each element.

The results of this experiment were not recorded in actual weights, but marked differences were noted in the appearance of the plants at the end of the experiment. One of the striking results obtained was the general depression of the plants when treated with lime, the loss amounting to from 14 to 40 per cent. Subsequent field trials confirm these results. S. Suzuki[a] suggests that the injurious effect of lime may be due to the neutralization of the acids exuded by the roots, in consequence of which less food becomes available to the plants. The depressing effect of liming rice soils is recognized in Japan. Dr. T. Nakamura informed the writer that the liming of rice soils in the Kiushu district of Japan is prohibited by law.

The general results of this experiment indicate that nitrogen in the form of sulphate of ammonia is especially suitable for the rice plant, and this fact was further borne out in plat experiments and also when tried on a field scale in a different locality. Where the nitrogen was supplied in the form of fish guano, the results agreed closely with those obtained where sulphate of ammonia was used. Next to the beneficial results obtained from nitrogen in the form of sulphate of ammonia and fish guano, acid phosphate seems to be the most avail-

[a] Bul. Col. Agr., Tokyo Imp. Univ., 6 (1905), No. 4, pp. 347–351.

FIG. 1.—COMPARISONS OF GOLD SEED AND JAPAN RICE. JAPAN SEED ON RIGHT, GOLD SEED ON LEFT.

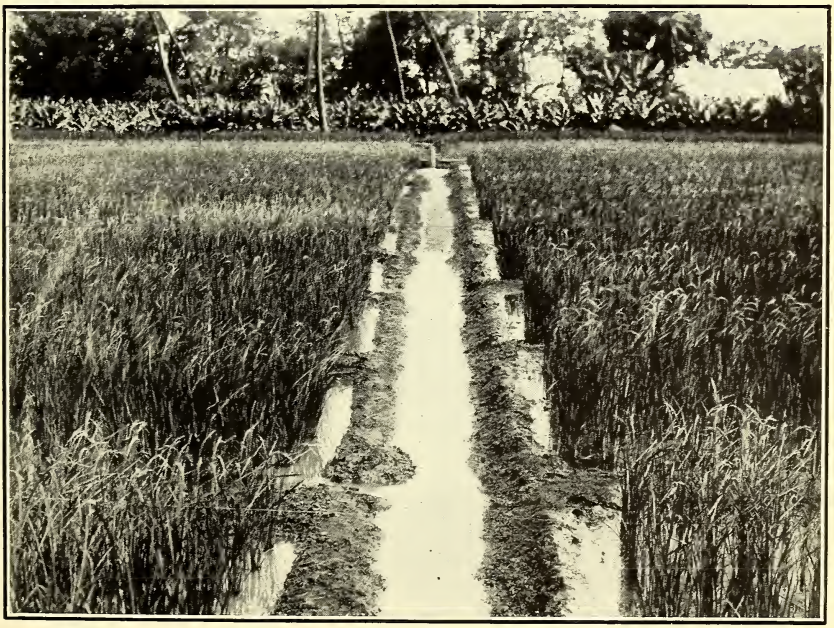


FIG. 2.—SHOWING METHOD OF IRRIGATING FERTILIZER PLATS.

able for the rice plant. The best combination of the two elements was distinctly in favor of nitrogen and phosphorus in the form of sulphate of ammonia and acid phosphate and fish guano and acid phosphate, the two combinations being of about equal value. Next to these combinations fish guano and sulphate of potash, sulphate of ammonia and Thomas slag, fish guano and Thomas slag, sulphate of ammonia and sulphate of potash, and fish guano and muriate of potash gave results in about the order named. Where a complete fertilizer made up of the several forms of these different fertilizers was used, practically all the plants were killed within a month.

EXPERIMENT III.

The object of this experiment was to determine the relative value of different fertilizers when applied to two widely different types of rice—the Hawaiian Gold Seed, a heavy-strawed, slow-maturing, starchy rice, the standard used by the Chinese, and the dwarf, early maturing, glutenous Japan rice, largely used by the Japanese (Pl. VIII, fig. 1). The field selected for this experiment had been devoted to rice culture for a number of years without any fertilization and it had uniformly produced a fair crop, the stand being characterized by an exceptional evenness of growth. A further advantage of this locality was an ample supply of pure artesian water and a fairly well sheltered location (Pl. VIII, fig. 2).

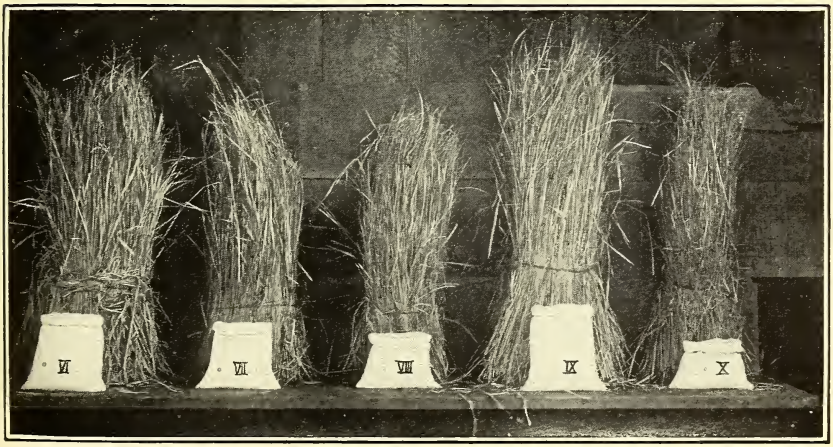
The fertilizers were supplied in as varied selection as the market afforded and such as can always be obtained in Honolulu. Where single constituents were added the amounts supplied in the fertilizer tests were 40 pounds of nitrogen, 25 pounds of phosphoric acid, and 45 pounds of potash, these quantities being based upon the plant food ingredients removed by a good crop of rice.

Each plat was divided into four sections. One was untreated, the second fertilized before planting, the third fertilized before planting and in addition limed at the rate of 750 pounds of air-slaked lime per acre, and the fourth was fertilized after the plants were three-fourths grown. Where the fertilizers were applied before planting they were worked into the dry soil and the soil left for one week, when the seed was drilled to a depth of 1 inch in rows 12 inches apart. Immediately after planting the plats were lightly flooded and the water at once permitted to recede.

Each plat was sown with two varieties of rice, the Hawaiian Gold Seed (No. 148) and the Japan Seed (No. 153). When the seedlings were 3 inches high they were thinned so as to stand 3 inches in the row, and the plats again flooded and the water allowed to cover the surface of the soil until nearly harvest.

The influence of lime in connection with and without the addition of fertilizers was determined. The uniformly negative results obtained from liming, while they can not be taken as a criterion for all rice soils, seem to show the error in indiscriminately recommending liming for all rice lands. Hawaiian rice lands are submerged for the greater part of the year, but only one out of six typical rice areas showed an acid reaction, and it is probable that this soil would have been benefited by liming.

The effect of the different treatments on the yield of Japan rice is shown in the accompanying table (see also Pl. IX).



EFFECT OF DIFFERENT FERTILIZERS ON YIELD OF JAPAN SEED PADDY AND STRAW.

[Numbers on bags correspond with plat numbers in table.]

Relative value of the various commercial forms of nitrogen, phosphoric acid, and potash as fertilizers for the rice crop.

Plat number.	Fertilizer applied.	Amount per acre.	Equivalent.	Check (untreated).				Fertilized before planting.				Limed (750 lbs.) and fertilized before planting.				Fertilized after plants were three-fourths grown.			
				Paddy.	Sterile glumes.	Straw.	Average of 10 plats.	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).
		Lbs.	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*
1	Nitrate of soda	266	40 N	3.54	56	4.55	Paddy 3.78 Straw 5.29	4.76	28	5.21	+ 25.92	3.18	85	4.20	−15.87	5.06	157	8.03	+33.33
2	Sulphate of ammonia	200	40 N	3.66	61	4.80		7.12	63	9.15	+ 88.36	3.37	105	4.68	−10.84	5.34	168	8.41	+41.27
3	Sulphate of potash	95	45 K_2O	3.93	59	5.20		10.15	84	13.09	+168.52	2.87	294	6.56	−24.07	2.90	84	5.08	−23.27
4	Sulphate of potash and magnesia	180	45 K_2O, 61 $MgSO_4$	3.81	44	5.55		9.06	112	12.81	+139.68	3.75	168	6.01	− 0.79	3.47	28	4.87	− 8.20
5	Acid phosphate	125	25 P_2O_5	4.02	70	6.10		8.75	119	13.15	+131.48	2.15	217	5.44	−43.12	4.59	94	6.98	+21.42
6	Reverted phosphate	156	25 P_2O_5	3.90	73	5.25		6.31	172	14.78	+ 66.93	2.06	112	3.81	−45.50	3.12	52	5.62	−17.46
7	Thomas slag phosphate	156	25 P_2O_5, 62 CaO	4.26	60	5.76		5.56	42	7.50	+ 47.07	2.75	147	5.43	−27.25	3.12	28	5.01	−17.46
8	Complete fertilizer (nitrate of soda, acid phosphate, and sulphate of potash)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.75	62	5.20		4.75	35	5.56	+ 25.66	3.12	140	4.48	−17.46	3.70	42	5.46	− 2.11
9	Complete fertilizer (sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.66	56	5.80		7.55	91	13.10	+ 99.73	3.37	103	3.93	−10.84	3.57	88	6.26	− 5.55
10	Complete fertilizer (nitrate of soda, Thomas slag phosphate, and sulphate of potash and magnesia)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.30	51	4.50		3.94	49	5.31	+ 4.23	3.00	63	3.75	−20.63	4.31	49	5.27	+14.02

In reviewing the figures it appears that the average production of the ten untreated plats was 3.78 pounds of paddy and 5.29 pounds of straw. The greatest gain in paddy from any one fertilizer when applied before the crop was planted was from sulphate of potash, which yielded a gain of 168 per cent over the untreated plats, an equivalent of 2,522 pounds of paddy per acre. This additional yield, valued at $2.50 per 100 pounds, represents an increased value of $63, produced at a cost of less than $5 for fertilizer. The next largest increase in yield was on plat 4, to which the double phosphate salts were added; the acid phosphate came next, the complete fertilizer composed of sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash next, followed by sulphate of ammonia, reverted phosphate, Thomas slag, nitrate of soda, etc. While all the fertilizers produced some gain, the experiment shows the importance of the particular form in which the different constituents are supplied.

Where the fertilizers were applied after the plants were three-fourths grown, as is the general Hawaiian practice, radically different results were obtained. As might have been expected, the nitrate of soda was more effective than where applied before planting, especially in the increase of straw. On the other hand, the slowly acting sulphate of ammonia showed a decrease in yield when the fertilizer was supplied during the growing period. All forms of potash appeared to have exerted a detrimental effect and the different forms of phosphate showed a considerable decrease as compared with the same fertilizers when added before planting. As in the other experiments, the addition of lime depressed the yield of grain in all cases and in many instances the amount of straw also.

In a second experiment, in which the Hawaiian Gold Seed variety of rice was used, results almost identical with those given in the above table were obtained. The greatest benefit was secured from the use of sulphate of potash when fertilizers were applied before planting, the benefits of the remaining treatments being about in the same order as described for the treatment with Japan rice. Two notable exceptions, however, were observed. The reverted phosphate gave only 66 per cent gain over the untreated plat with the Japan Seed, while the gain for the Gold Seed amounted to 132 per cent. In a similar way the complete fertilizer used on plat 10, which gave only 4 per cent increase with the Japan Seed, showed an increase of 86 per cent for the Gold Seed. These increases may possibly be explained by the fact that the season of growth of the Gold Seed is fully forty days longer than that of the Japan Seed, and it is reasonable to believe that this additional growing period rendered available a proportionate additional amount of the slowly soluble constituents in these forms of fertilizers.

In comparing the limed section in this experiment with the experiment with the Japan rice it was noticed that a less depressing effect was exerted on the slower growing variety, although a considerable decrease as compared with the corresponding plats not limed was apparent.

Where the plants were fertilized when they were two-thirds grown practically the same beneficial effects for nitrate of soda and sulphate of ammonia were noted for both varieties of rice. The sulphate of potash, which slightly decreased the yield of Japan Seed when applied after the crop was well advanced, appeared to exert a slight benefit on the later maturing Gold Seed variety. Slightly beneficial effects were also obtained from the acid phosphates, reverted phosphates, and complete fertilizers.

EXPERIMENT IV.

Less than a decade ago practically the only fertilizers used in Hawaiian rice culture were fish refuse (fish guano and shrimp skins), Chinese peanut cake, and stable manure, the first two being imported either from China or from California in large quantities. At present stable manure is about the only material used, the high price of importations from China and the scarcity of materials elsewhere prohibiting their general use. The beneficial effect resulting from this class of manures is often commented upon by Chinese rice growers, and it was on this account that an experiment was planned to compare the value of these old-time fertilizers with the modern commercial manures.

Accordingly plat experiments were carried out with Japan Seed rice, using the materials available at Honolulu at the time. These were Chinese peanut cake, fish guano, and stable manure. The shrimp skins, once so largely used, were unobtainable, and a much-advertised and largely used commercial fertilizer was substituted. Owing to its concentration and extreme solubility it was thought that such material might possess useful features if produced cheaply enough.

A partial analysis of the fertilizing materials was made by the station chemist, and showed that the horse manure contained 0.41 per cent of nitrogen, 0.507 per cent of phosphoric acid, and 0.471 per cent of potash, and the fish guano 8.58 per cent of nitrogen and 6.95 per cent of phosphoric acid. The analysis of the commercial fertilizer was furnished by the manufacturer, and it is claimed that the substance contains 15 per cent of nitrogen, 5 to 6 per cent of water-soluble phosphoric acid, and 3 to 4 per cent of potash.

As in the previously described experiments, each plat received different treatments, some being fertilized before planting and others

when the plants were two-fifths grown. On some plats lime was used, while on others it was omitted.

As in practically all the other experiments, the addition of lime seemed to exert a depression in the yield of the crop, except on the plat receiving stable manure at the rate of 5 tons per acre.

In comparing the relative value of the application of fertilizers before sowing the crop with the results obtained where the fertilizers were applied after the crop had become well advanced, there appeared to be little difference so far as the experiments with Chinese peanut cake were concerned, but since the results in either case were poor, no weight is attached to this part of the experiment. On the other hand, the fish guano showed a decided gain in the application made before the crop was sown. This was also true of the commercial fertilizer.

In comparing the relative value of the several fertilizing materials, stable manure showed an increase of 121 per cent of paddy for an application of 2½ tons per acre, while an application of 5 tons per acre yielded 250 per cent increase over the check and over 100 per cent more than the section receiving half as much manure. The application of stable manure also greatly increased the yield of straw in proportion to the amount of grain. Next in value to the stable manure was the fish guano, which gave an increased yield of 118 per cent over the check plat, followed by the commercial fertilizer with an average gain of 100 per cent when it was applied at the rate of 100 pounds per acre. It was thought that the extreme solubility of the materials composing the commercial fertilizer would especially adapt it as a food stimulant in later applications, but this does not appear to hold true so far as this experiment is concerned. The late application of fish guano resulted in a considerable decrease in the yield as compared with the early application.

Comparing the results of the same treatment upon the Gold Seed variety a close agreement was found throughout the experiment.

EXPERIMENT V.

This and the two following experiments were carried on in cooperation with the Punaluu rice plantation, situated on the north side of the island of Oahu. This plantation was established in 1872, and it had been cropped twice annually until decreasing yields made rice culture on this land unprofitable except in years of exceptionally high prices. The yield from 37 acres of this tract for the 1907 spring crop amounted to 74,000 pounds of paddy, or an average of 2,000 pounds per acre. A part of this was produced on fertilized land, and a portion of the land had been fallowed for a season or two.

An acre tract of the poorest of these lands was set aside for these experiments, the object of which was to compare the relative value in economy of several complete fertilizers under different modes of

application. The fertilizers in the first experiment were applied April 30, 1907, when the crop was about half grown, and they consisted of a special fertilizer made up of fish guano, acid phosphate, and sulphate of potash and magnesia, and a regular fertilizer which is more or less commonly used, which consisted of nitrate of soda, sulphate of ammonia, acid phosphate, and muriate of potash. These compounds were used alone and, in the case of the special fertilizer, in combination with sulphate of ammonia. They were applied by broadcasting on receding water, broadcasting and working into the soil to a depth of 2 inches, and broadcasting on the dry surface before reflooding.

The yield of paddy on the untreated plats was 2,888 pounds, the highest yield ever produced on this land without the use of fertilizer. It is thought possible that this large yield may have been due to the application of fertilizers to the adjoining plats. In making comparisons, however, the actual weights of crops were taken.

Where the special fertilizer was used and worked into the ground to a depth of several inches, 58.5 per cent gain, equivalent to $29.60 net profit per acre, was obtained, the cost of the fertilizer and labor involved in working it into the ground being deducted. Where the fertilizer was not worked into the ground an increase of 42.5 per cent was obtained, representing a net profit of $20.75. From this it will be seen that at a cost of $2 for working in the fertilizer an additional profit of about $10 was obtained. The special fertilizer yielded an increase of 35 per cent when applied alone, only 17.5 per cent less than when sulphate of ammonia was added to it.

In these experiments the regular fertilizer exerted very little beneficial effect, due probably to the low nitrogen content, which is the most striking deficiency.

The residual effect of the fertilizers is shown by the striking growth of the second crop on the treated plats.

EXPERIMENTS VI AND VII.

In conjunction with Experiment V two special nitrogen fertilizing experiments were undertaken on a field scale. Two forms of nitrogen were used, sulphate of ammonia at $72 per ton and nitrate of soda at $55 per ton, these prices representing the Honolulu quotations in November, 1907.

The sulphate of ammonia was applied at the rate of 75 and 100 pounds per acre and the nitrate of soda at the rate of 100 and 150 pounds per acre. All the applications were made at the same time, when the plants were a little more than half grown. The methods of application were those usually practiced by the Chinese growers, i. e., to broadcast the fertilizer upon the receding flood water just before

the drying-off period, which in Hawaiian rice culture precedes the flowering stage of the rice plants.

The results of these experiments show that the sulphate of ammonia proved very efficient, and increases of 80 and 85 per cent were obtained from applications of 75 and 100 pounds, respectively. This gain was produced at the cost of $2.70 and $3.60 for material and resulted in a net profit of $35.15 and $36.50, respectively, for the different applications. The application of 100 pounds of sulphate of ammonia gave an increase of only 5 per cent over the application of 75 pounds per acre, amounting to a cash increase of only $1.35, which barely paid for the additional fertilizer. Where nitrate of soda was applied at the rate of 100 pounds per acre the gain was 21 per cent, equivalent to a net profit of $12. These results between the two forms of nitrogen are in practical agreement with those given in the pot experiments described above.

It seems reasonably certain from these and the other experiments that sulphate of ammonia is better suited to the rice crop than nitrate of soda, at least when both are applied in single applications to neutral soils. It is probable that better results can be obtained from nitrate of soda when it is applied two or three times during the growing season, particularly should the soils be acid. When it is remembered that the nitrogen in ammonium salts becomes available more slowly and gradually than in the nitrates and that nitrification takes place rapidly in saturated and submerged soils, there is probably a great waste when too large amounts of nitrate of soda are applied at one time, and an experiment has been planned to test this point in regard to the rice soils of Hawaii.

CULTURE EXPERIMENTS.

INFLUENCE OF AGE OF SEEDLINGS AT TIME OF TRANSPLANTING.

Throughout this report frequent reference has been made to the influence upon yield exerted by the age of seedlings at the time of transplanting. In the table on page 89 are given the results of an experiment in which seedlings 20, 25, 30, and 35 days old, respectively, were transplanted under otherwise identical conditions. All the seed had been sown on February 27 and the seedlings began to appear above ground on March 2.

The yield of Japan seed rice (No. 153) as influenced by age of seedlings at time of transplanting.

Experiment No.	Age of seedlings at time of transplanting.	Date of transplanting.	Date of flowering.	Date of maturity and harvest.	Yield from three 100 square feet cuttings.		Relative yields, experiment 1 taken as 100.	Calculated yields per acre.		Value of paddy per acre.[a]
					Paddy.	Straw.		Paddy.	Straw.	
					Lbs.	*Lbs.*		*Lbs.*	*Lbs.*	*Dollars.*
1	20 days old	Mar. 22	May 8	June 10	29.00	27.75	100	4,205	4,024	105.12½
2	25 days old	Mar. 27	...do	...do	25.50	24.50	87.93	3,697	3,553	92.42½
3	30 days old	Apr. 1	May 6	...do	22.25	22.50	76.72	3,126	3,263	78.15
4	35 days old	Apr. 6	May 5	...do	13.25	18.00	45.69	1,921	2,610	48.02½
5	20 days old (fertilized)..	Mar. 22	May 9	...do	32.50	48.00	112.07	4,713	6,960	117.82½

[a] At $2.50 per 100 pounds.

By referring to experiment 1 it will be seen that the maximum yield was obtained from seedlings 20 days old at the time of transplanting and that a gradual and considerable decrease in yield resulted from each subsequent transplanting, the yields being almost in a direct diminishing ratio to the increased age of the seedlings. The importance of this phase of rice culture wherever the crop is transplanted, as it is in Hawaii and Oriental countries generally, can not be too strongly dwelt upon, since 10 days' delay in transplanting seedlings may decrease the yield of paddy almost one-half. It is to be remembered, however, that this loss, at least in this experiment, applies particularly to the quick-maturing varieties. Much less striking results were obtained from a preliminary experiment with a Hawaiian type of rice that required 140 days for maturity. The loss in yield due to the increased age of the seedlings at the time of transplanting was less than half that reported for the Japan type.

It will be noted in experiment 5 that in addition to being planted with 20-day-old seedlings the plat received 350 pounds of complete fertilizer, and that this addition resulted in increasing the yield only 12 per cent over the unfertilized plat. A part of each of the other plantings was likewise fertilized, and this resulted in a considerably greater gain in the plats planted to 25 and 30 day old seedlings. It is believed that the older seedlings having had their growth retarded were more largely influenced by the fertilizer than those which were transplanted at a more favorable season.

EXPERIMENTS IN BROADCASTING, DRILLING, AND TRANSPLANTING RICE.

An experiment was undertaken to test the relative value for Hawaiian conditions of two distinct methods of planting—the direct sowing of seed, as practiced in the southern United States, and the Hawaiian and Oriental custom of transplanting the seedlings. All the seed was sown on February 27. One lot was broadcasted at the

rate of 50 pounds per acre and another lot of the same stock of seed drilled in rows 12 inches apart at the same rate per acre. When well established the seedlings in both cases were thinned out to a stand of approximately 200,000 plants per acre, to conform as closely as possible with the stand of transplanted plants.

The results of this experiment are shown in the accompanying table:

Relative yields from broadcasted, drilled, and transplanted Japan seed rice (No. 153).

Experiment No.	Method of culture.	Date of germination.	Date of flowering.	Date of maturity and harvest.	Height of plants.	Average number of fruiting culms per plant.	
						Primary.	Secondary.
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	Mar. 2–5	May 1–5	June 6	*Inches.* 23–24	2–3	1–2
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	....do ...	.....do	....do ...	25–28	2–3	1–2
3[a]	Seedlings 20 days old at transplanting	Mar. 2	May 8–10	June 10	32–34	6–8	1–3
4[a]	Seedlings 35 days old at transplanting	....do ...	May 3–5	....do ...	20–22	2–4	1–2

Experiment No	Method of culture.	Yield from three 100 square foot cuttings.		Calculated yields per acre.		Value of paddy per acre.[b]
		Paddy.	Straw.	Paddy.	Straw.	
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	*Pounds.* 12.25	*Pounds.* 17.95	*Pounds.* 1,776	*Pounds.* 2,501	*Dollars.* 44.40
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	13.50	15.50	1,958	2,393	48.95
3[a]	Seedlings 20 days old at transplanting	29.00	27.75	4,205	4,024	105.12½
4[a]	Seedlings 35 days old at transplanting	13.25	18.00	1,921	2,610	48.02½

[a] Taken from preceding table. [b] At $2.50 per 100 pounds.

It will be seen from experiment 3 that the seedlings 20 days old at the time of transplanting yielded more than either the broadcasted or drilled seed, the increased cash value being more than $50 per acre for the transplanted stock. On the other hand, when the seedlings were 35 days old at the time of transplanting the yields were about equal to those from direct sowing.

The differences in yield due to broadcasted or drilled seed are hardly sufficient to warrant definite conclusions. It is believed, however, that greater uniformity of stand and economy of seed are obtained by drilling.

The cost of transplanting an acre of rice in Hawaii does not exceed $6. Four men can transplant an acre per day, setting out 50,000 clumps, consisting of from 4 to 8 seedlings each.

From the above table it is readily seen that under present Hawaiian conditions the transplanting method in rice culture is amply justified.

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